Liability for Damage Caused by GMOs: An Economic Perspective

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Liability for Damage Caused by GMOs: An Economic Perspective

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I. INTRODUCTION

The application of genetic modification in agriculture offers remarkable benefits not only for farmers, but also for consumers. This technological development promises the increase in productivity and decrease in chemicals used in agriculture. In addition, the technology also offers enhanced taste, better nutritional ingredients, and cheaper products for consumers.[1] For example, some studies show that the decrease in the use of pesticides and herbicides corresponds to the increased adoption of, respectively, insect-resistant crops and herbicide-tolerant crops.[2] Authors have also argued that the rapid adoption of genetically modified (GM) crops occurs because farmers gain remarkable economic benefits from adopting GM crops, including the reduction of chemical sprays, yields improvement, increased yields, labor savings, and the shifts to a system that requires less tillage.[3]

Scientists are also developing crops able to resist environmental stresses, such as drought, and contain nutritional contents, such as vitamin A, which are especially beneficial for people in poor countries. Genetically Modified Organisms (GMOs) are thus another miracle created by humans, both to increase profits and overcome hunger and malnourishment. Many developing countries have embraced this technology with the hope that this technology will help the

1. *See* John Charles Kunich, *Mother Frankenstein, Doctor Nature, and the Environmental Law of Genetic Engineering*, 74 S. CAL. L. REV. 807, 810 (2001).

2. L.L. Wolfenbarger & P.R. Phifer, *The Ecological Risks and Benefits of Genetically Engineered Plants*, 290 SCI. 2088, 2090-91 (2000).

3. Martina McGloughlin, *Ten Reasons Why Biotechnology Will Be Important to the Developing World*, 2 AGBIOFORUM 163, 165-66 (1999); *see also* Janet Carpenter & Leonard Gianessi, *Herbicide Tolerant Soybeans: Why Growers are Adopting Roundup Ready Varieties*, 2 AGBIOFORUM 65, 68-69 (1999) (arguing growers are switching to a particular weed control program because of its simplicity and flexibility). Similarly, Kalaitzandonakes summarizes the farmers' economic benefits from adopting GM crops in terms of cost reductions in pest management, increased yields, improved insurance against pests, time savings, reduction in equipment due to no tillage is required, and land-use efficiency gains. Nicholas Kalaitzandonakes, *A Farm Level Perspective on Agrobiotechnology: How Much Value and for Whom?*, 2 AGBIOFORUM 61, 62 (1999).

countries boost their agricultural productivity. Despite these promises, GMOs, as a relatively new technology, also impose potential adverse effects on human health and the environment. Public concerns have surfaced, and although uncertain at this time, these possible effects might be irreversible and uncontrollable once they materialize.[4] Notwithstanding the potential benefits of GMOs as far as overcoming hunger (a major concern for most of the developing world today) there is indeed also major concern with respect to the potential negative consequences of the use of GMOs. One such risk is the issue of co-mingling between non-GM and GM crops. As a result of this admixture, GM crops could also be found in the food or feed production chain of non-GM crops.[5] Damage could also result, for example, from the fact that genes of GM crops designed to be tolerant for the application of certain herbicides (herbicide tolerant crops) have the potential of flowing to their weedy relatives, which could then result in the development of herbicide resistant hybrids. This could increase the cost of weed controls and place pressure on the environment as farmers are forced to resort to chemicals that are possibly more toxic.[6]

Other concerns relate to the fact that some GM crops may be insect-resistant. These crops have been genetically modified with genes from *bacillus thuringiensis*, referred to as Bt crops. Insects eating these crops will be killed, but these self-producing pesticide plants may create several environmental problems, such as the development of pest-resistance.[7]

With the growing use and international trade of GM crops or products, the question arises as to who should be held liable if those potential adverse impacts eventually materialize. Liability and redress are thus important aspects accompanying the development and commercialization of GMOs. The importance of liability and redress has been addressed in the Cartagena Protocol on Biosafety, which calls for parties to adopt appropriate international rules and procedures in the field of liability and redress.[8]

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4. Applegate argues that the dangers posed by genetic engineering are real. They may take form as weeds, pests, and diseases that are invasive and resistant to chemical control, as well as the degradation of genetic diversity, and as novel toxins and food allergies. John S. Applegate, *The Prometheus Principle: Using the Precautionary Principle to Harmonize the Regulation of Genetically Modified Organisms*, 9 IND. J. GLOBAL LEGAL STUD. 207, 208 (2001).

5. It is, however, debated, to what extent this risk of co-mingling between GM and non-GM crops does necessarily create economic damage for e.g. organic farms. *See* Drew L. Kershen, *Legal Liability Issues in Agricultural Biotechnology*, 44 CROP SCI. 456, 457 (2004).

6. *See* David E. Ervin et al., *Towards an Ecological Systems Approach in Public Research for Environmental Regulation of Transgenic Crops*, 99 AGRIC., ECOSYSTEMS & ENV'T 1, 5. (2003).

7. *See* Sandra S. Batie, *The Environmental Impacts of Genetically Modified Plants: Challenges to Decision Making*, 85 AM. J. OF AGRIC. ECON. 1107, 1108 (2003); Wolfenbarger & Phifer, *supra* note 2, at 2089-92 (discussing effects of Bt crops on non-target species and development of resistance to Bt toxins).

8. In this regard, one may refer to Article 27 of the Cartagena Protocol, which reads:

> "The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first meeting, adopt a process with respect to the appropriate elaboration of international rules and

One aspect closely related to the issue of liability is the requirement that the damage incurred should be foreseeable at the time the damaging activity occurs. The issue of foreseeability inevitably requires an analysis of the possible impact of GMOs, which may have different levels of certainty. It is in this regard that the precautionary principle has been proposed in order to lessen the foreseeability requirement. Incorporating the precautionary principle into liability thus means that despite current uncertainties concerning some impacts of GMOs, GM operators will be held liable if these effects materialize and their GM products turn out to be harmful.

This paper attempts to provide an economic analysis regarding the application of liability rules and the incorporation of the precautionary principle into liability schemes for damage caused by GMOs. The economic analysis of law has generally paid considerable attention to the question of how legal instruments, and legal rules in particular, can promote social welfare in society. In addition, much of law and economics research has focused on uncertainties that arise as a result of the use of GMOs. In that respect, for example, questions arise as to whether GMOs should be used at all when uncertainties arise regarding their consequences, particularly the consequences for third parties. This led to challenges, for example, with respect to the application of the well known precautionary principle.[9]

In the introduction it should be stated that for an economic analysis it is always important to make a distinction between prevention and compensation. For an economist, liability rules should primarily have a preventive effect, and thus provide incentives to those dealing with GMOs in order to prevent damage from occurring to third parties. In economic literature this preventive goal is distinguished from ex post compensation. Ex post compensation can be provided through a variety of mechanisms. Tort law is not usually considered a tool for compensation in economic literature; rather, the main goal of tort law for economists is its preventive mechanism. Hence, it is insurance or compensation funds that could fulfill this particular objective.

This contribution is structured as follows: first, the paper will discuss possible impacts of GMOs (II). The discussion will then turn to the types of liability applicable to GMO risks; this is the core of the paper, since a distinction will be made between the general case where victims are third parties, the application of liability rules to environmental damage, and the product liability case (III). An important and debated issue in GMO liability is the question of how one should deal with causation. That will be dealt with in detail in Section IV. Related to the

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procedures in the field of liability and redress for damage resulting from transboundary movements of living modified organisms, analysing and taking due account of the ongoing processes in international law on these matters, and shall endeavour to complete this process within four years."

9. *Cf.* Helle Tegner Anker & Margaret Rosso Grossman, *Authorization of Genetically Modified Organisms: Precaution in U.S. and E.C. Law*, 4 EUR. FOOD AND FEED L. REV 3 (2009) (Ger.).

causation issue is the question of how liability should be allocated if the damage is not caused by one tortfeasor, but if multiple tortfeasors are involved (V). Defendants in a GMO related liability case may be able to call on several defenses which are discussed in Section VI. Finally, the question arises, if liability of the defendant is accepted, what remedies are available for the plaintiff. This involves *inter alia* a discussion of damages, including the question of whether from an economic perspective there should be liability for so called pure economic loss, as well as the questions of whether an injunction can be sought for, and whether compulsory insurance may be indicated. These issues related to remedies are addressed in Section VII. We formulate concluding remarks in Section VIII.

II. POSSIBLE IMPACTS OF GMOS

As stated earlier, despite all promises of the potential benefits, the development and commercialization of GMOs also have a potential negative impact on humans and the environment. Discussion about these impacts is important not only to explain possible damage caused by GMOs, but also to provide an overview of the debate considering these impacts, which is especially useful for the discussion of defenses and foreseeability.

In addition to human health problems,[10] GMOs may also create adverse environmental impacts, some of which are feared to be catastrophic. Typical concerns about the environmental impacts of GMOs can be summarized as follows:

A. GENE TRANSFER

There are, at least, three separate issues related to gene transfer from GM crops.[11] The first issue arises when a GM crop from one land cross-pollinates

10. Concerns over the impacts on human health include the issue of allergen and the use of antibiotic as gene marker. For discussion about possible impacts on human health, see generally Anita Bakshi, *Potential Adverse Health Effects of Genetically Modified Crops*, 6 J. TOXICOLOGY AND ENVTL. HEALTH, PART B: CRITICAL REVIEWS 211 (2003).

11. Once released into the environment, genes from GM crops may be transferred, through several possible ways, into the genes of other plants. According to the Royal Society of Canada, GM crops can be categorized in the possibility for gene transfer into: 1) no possibility, where wild relatives are absent from the region where the crop is grown; 2) low possibility, where crops species are either predominantly self-propagated (*e.g.*, many cereals) or are infrequently propagated by sexual reproduction and flower (*e.g.*, sweet potato, sugar cane); and 3) moderate to high possibility, where the crops are grown in an area where their sexually compatible wild relatives are present (e.g. canola in Europe and North America, and rice in South East Asia). ROYAL SOC'Y CAN., ELEMENTS OF PRECAUTION: RECOMMENDATIONS FOR THE REGULATION OF FOOD BIOTECHNOLOGY IN CANADA: AN EXPERT PANEL REPORT ON THE FUTURE OF FOOD BIOTECHNOLOGY 124-25 (2001), *available at* http://www.rsc.ca/files/publications/expert_panels/foodbiotechnology/GMreportEN.pdf (last visited Jan. 13, 2011) (*hereinafter* RSC). Others have characterized the risks of genes flow as follows: a) Very low and low risks; crops in this group show low level, or even do not show evidence at all, of cross-pollination with wild relatives. Corn,

with a non-GM crop of the same species from surrounding land. Where GM crops are grown in the same region as non-GM cultivars, opportunities for cross-pollination exist. One of the most cited studies about this issue is the work of Quist and Chapela published in *Nature* in 2001, which observed that genes from GM corn had been transferred, referred to as "introgression," into non-GM corn fields in Mexico.[12] Economic damage from the gene-transfer ranges from a possible loss of certification as an organic farm, to losing markets because the products have been "contaminated" by GM crops.[13] In addition, there is also a real possibility that a farmer whose land has been polluted by a neighboring GM farm could even be found guilty of patent infringement.[14]

The second issue of gene flow corresponds to the invasiveness of new hybrids from GM crops and their wild relatives.[15] GM crops, such as herbicide-tolerant and insect-resistant crops, have phenotypes that are designated to increase the fitness of these crops. Such fitness-related enhancement traits could be transferred into wild relatives.[16] The invasiveness of new hybrids could replace the wild species and, hence, reduce the genetic diversity and uniqueness of wild-

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soybean, tomato, and potato are considered to belong to this group; b) Moderate risk; crops, such as alfalfa, sugar beet, and sunflower, could be included into this moderate group. These species have the same genus and similar chromosomes numbers with wild relatives, and there is some evidence about hybridisation of these species with their wild relatives; c) High risk; crops belong to this group are considered to hybridise easily with their wild relatives. Examples of these crops include canola and sorghum. Allison A. Snow & Pedro Morán Palma, *Commercialization of Transgenic Plants: Potential Ecological Risks*, 47 BIOSCIENCE 86, 91 (1997); C. Neal Stewart Jr., Matthew D. Halfhill & Suzanne I. Warwick, *Transgene Introgression from Genetically Modified Crops to Their Wild Relatives*, 4 NATURE REVIEWS GENETICS 806, 810-12 (2003).

12. For a complete result, see David Quist & Ignacio H. Chapela, *Transgenic DNA Introgressed into Traditional Maize Landraces in Oaxaca, Mexico*, 414 NATURE 541 (2001).

13. Concerns of losing the entire organic market due to the mixture of crops has motivated Canadian groups of organic farmers to sue two giant GMO producers, Monsanto and Aventis. The farmers argue that the entire organic market for wheat, worth as much as $17.5 million, is threatened due to the commercialization of GM wheat in Canada. *See* Aaron Bouchie, *Organic Farmers Sue GMO Producers*, 20 NATURE BIOTECHNOLOGY 210, 210 (2002).

14. One could refer here to the famous Monsanto v. Schmeiser case, in which the Canadian court found the defendant guilty for infringement of Monsanto's patent rights for herbicide-resistant canola. *See* Jeffrey L. Fox, *Canadian Farmer Found Guilty of Monsanto Canola Patent Infringement*, 19 NATURE BIOTECHNOLOGY 396, 396-397 (2001). The ruling of the court in this case has, however, been severely criticized as the court ignored the fact that the defendant did not use glyphosate, herbicide which the patented GM canola is supposed to resist. Some authors argue that if the possession of hybrids containing the patented gene is considered a sufficient ground for the infringement of a patent right, then the court should have seriously take into account the question of the defendant's intent. Otherwise, a farmer whose land has been contaminated by GM crops, and hence, who unwillingly grows the hybrids, will be found guilty for patent infringement. *See* Maria Lee and Robert Burrell, *Liability for the Escape of GM Seeds: Pursuing the 'Victim'?*, 65 MOD. L. REV. 517, 523-525 (2002), *see also* Hilary Preston, *Drift of Patented Genetically Engineered Crops: Rethinking Liability Theories*, 81 TEX. L. REV. 1153, 1167-1169 (2003).

15. Although crop-to-wild hybridisation has already been a common phenomenon in agriculture for years, the introduction of GM crops could increase the likelihood of such a hybridisation to occur.

16. Norman C. Ellstrand, *When Transgenes Wander, Should We Worry?*, *in* ENGINEERING THE FARM: THE SOCIAL AND ETHICAL ASPECTS OF AGRIC. BIOTECHNOLOGY 61, 65 (Britt Bailey & Marc Lappé eds., 2002).

native populations.[17] In this regard, as Johnson has argued, the acquisition of resistance in wild plants may change plant population dynamics, increasing the risks of their invading agricultural land and natural ecosystems.[18]

The greatest concern regarding genes transfer is perhaps the possibility that the transfer from GM crops to their sexually compatible wild relatives may result in unwanted hybrids that are more persistent. According to Ervin et al., there is little doubt among scientists that genes will wander from crops into the wild. They argue that the relevant questions are whether transgenes will survive in the wild and how they confer a certain trait to particular wild plants that make such plants more difficult to control.[19] This means that the real issue is not whether genes will move, but rather whether they could survive and increase the so-called "weediness" (persistence) of unwanted wild plants. Some studies in Western Canada show that three different herbicide-resistant canola (rape) varieties have cross-pollinated to create canola plants that are resistant to multiple types of herbicide.[20] The presence of such a "superweed" could force farmers to use older and less environmentally friendly herbicides.[21] In this regard, the large-scale introduction of GM crops might, therefore, change wild-weedy relatives into new and less manageable weeds.[22] Along with the creation of invasive hybrids, the presence of persistent hybrids, which require a more toxic application of herbicides, could also be considered a threat to the biological diversity of weeds in the natural ecosystems.[23]

B. THE DEVELOPMENT OF RESISTANCE

The introduction of novel crops with fitness-enhanced genes could lead to an undesirable effect of resistance. Some biologists believe that eventually weeds will begin to develop resistance, and, hence, more application of possibly

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17. *See* Wolfenbarger & Phifer, *supra* note 2, at 2088. If, however, the hybrids show lower fitness than their parents, the wild population may shrink. Hence, hybridisation seems to create a problematic situation between the shrink of population and the invasiveness of the hybrids. *See* D.A. Andow & Claudia Zwahlen, *Assessing Environmental Risks of Transgenic Plants*, 9 ECOLOGY LETTERS 196, 200 (2006).

18. Brian Johnson, *Genetically Modified Crops and Other Organisms: Implications for Agricultural Sustainability and Biodiversity, in* AGRIC. BIOTECHNOLOGY AND THE POOR 131, 133 (G.J. Persley & M. M. Lantin eds., Consultative Group on International Agricultural Research 2000).

19. David E. Ervin et al., *supra* note 6, at 5.

20. One of the studies shows that the spontaneous hybridisations occurred among three varieties of canola, two of which were transgenic canola, when they were planted close to one another. The hybridisation of these varieties, each of which was resistant to glufosinate, imidazolinone and glyphosate, has resulted in hybrid volunteers that were resistant to more than one of these herbicides. In addition, the study also found that the resistant alleles were able to move rapidly. Norman C. Ellstrand, *Current Knowledge of Gene Flow in Plants: Implications for Transgene Flow*, 358 PHIL. TRANS. R. SOC. LOND. B. 1163, 1167 (2003).

21. RSC, *supra* note 11, at 122-23.

22. Miguel A. Altieri, *The Ecological Impacts of Transgenic Crops on Agroecosystem Health*, 6(1) ECOSYSTEM HEALTH 13, 16 (2000).

23. Philip J. Dale et al., *Potential for the Environmental Impact of Transgenic Crops*, 20 NATURE BIOTECHNOLOGY 567, 571 (2002).

increasingly toxic herbicides will be required.[24] Krimsky and Wrubel predict that the widespread use of herbicide resistant crops is likely to increase the reliance on a few herbicides.[25] Such widespread use of crops developed for resistance to single herbicides could put more pressure on weeds to evolve resistance to these herbicides.[26] Therefore, herbicide tolerant crops developed for a single application of certain herbicides could increase the likelihood of resistant development in weeds. To control these stronger weeds, farmers might resort to other chemicals that are possibly more toxic or to more aggressive tillage techniques that are likely to create soil erosion problems.[27]

The possibility of resistance development by insects has also been shown. Some studies, at least in laboratory experiments, have observed the existence of insects that can develop their resistance to Bt toxins.[28] With this evidence, one could argue that the release of GMOs into the environment could increase the possibility of resistance development in some target insects. In this regard, Anderson argues that, in contrast to the occasional use of Bt in organic farming, crops that are genetically engineered to contain Bt (hereinafter called 'Bt crops') produce toxins constantly while growing, which means that insects are continually exposed to the toxins, and therefore are under constant pressure to develop resistance.[29] The development of resistance to Bt toxins might engender serious environmental problems. *Bacillus thuringiensis*, once considered a miracle for agriculture, will rapidly become useless as pests become resistant to the bacteria that are massively and continually produced by Bt crops.[30] Some experts have even predicted that the development of pest resistance to Bt crops is inevitable; the question, however, is how fast this will occur.[31] The report of the U.S. Environmental Protection Agency (EPA) in 1998 predicted that most target insects could be resistant to Bt toxins within three to five years.[32]

According to the report of the Royal Society of Canada (RSC), the presence of insects that are resistant to Bt toxins, politically often referred to as the "superpests," could result in two undesirable effects. *First*, since Bt is the most

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24. David Pimentel, *Overview of the Use of Genetically Modified Organisms and Pesticides in Agriculture*, 9 IND. J. GLOBAL LEGAL STUD. 51, 57 (2001).

25. SHELDON KRIMSKY & ROGER P. WRUBEL, AGRICULTURAL BIOTECHNOLOGY AND THE ENVIRONMENT: SCIENCE, POLICY & SOCIAL ISSUES 46 (1996).

26. *Id.* at 46-47.

27. Sandra S. Batie, *supra* note 7, at 1108.

28. Laboratory research conducted by Tabashnik has reported an increase of resistance to Bt toxin in Lepidoptera (butterflies and moths), Coleoptera (beetles) and Diptera (mosquitoes and flies). *See* Bruce E. Tabashnik, *Evolution of Resistance to Bacillus Thuringiensis*, 39 ANN. REV. ENTOMOLOGY 47, 49, 54 (1994).

29. LUKE ANDERSON, GENETIC ENGINEERING, FOOD, AND OUR ENVIRONMENT 28 (1999).

30. Miguel A. Altieri & Peter Rosset, *Ten Reasons Why Biotechnology Will Not Ensure Food Security, Protect the Environment and Reduce Poverty in the Developing World*, 2 AGBIOFORUM 155, 157 (1999).

31. Miguel A. Altieri & Peter Rosset, *Strengthening the Case for Why Biotechnology Will Not Help the Developing World: A Response to McGloughlin*, 2 AGBIOFORUM 226, 229 (1999).

32. ANDERSON, *supra* note 29, at 28.

effective biological insecticide available to organic farmers, the diminishing of its effectiveness means that organic farming loses its control over pests, which could seriously affect this more ecologically friendly form of agricultural practice. *Second*, if conventional farmers resort to increased applications of chemical insecticides to control populations when GM plants no longer offer sufficient levels of protection against pest species, there is a possibility of a serious environmental impact resulting from the use of more toxic chemicals in agriculture.[33]

In addition, the report of the RSC also indicates a potential impact of the insect resistant crops on the secondary target pests, which used to be controlled by the repeated applications of insecticides against the primary pests. The report states that although the use of Bt crops has decreased the number of sprays used against the target pest, it has increased problems with secondary pests which, in the absence of the sprays against the primary pests, become more likely to develop since they are unaffected by the toxins from the sprays against the primary pests.[34]

C. EFFECTS ON NON-TARGETS

Some authors also have concerns about the impact of Bt crops on non-target herbivores and insects, such as lacewings, ladybird beetles, monarch butterfly larvae, and soil biota.[35] Some studies have, indeed, indicated the possibility of those impacts. For example, a laboratory study of Losey et al. observes forty-four percent mortality rate in monarch butterfly larvae fed on milkweed leaves dusted with Bt corn pollen, while no mortality is observed in monarchs fed on leaves with non-Bt corn pollen.[36] Another study concerning the impact of GM crops on non-targets is by Hilbeck et al. In this case, Hilbeck et al. observe that lacewings, being important and beneficial insects, experienced higher mortality rates when fed pests reared on Bt corn compared to when they were fed the pests reared on non-Bt corn.[37] The authors also detect no significant difference in mortality when the lacewings were fed with different preys that were similarly fed with Bt and no difference in mortality when the lacewings were fed with different preys that

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33. The RSC concludes that this case will result in two undesirable effects: i) Bt is the most effective biological insecticide available to organic farmers; the loss of it means the loss of control that seriously jeopardises their livelihood and endangers an expansion of this more ecologically friendly form of agricultural practice; ii) the possibility of a serious environmental impact if conventional farmers resorted to increased applications of chemical insecticides to control populations when GM plants no longer offer sufficient levels of protection against pest species. RSC, *supra* note 11, at 141.

34. *Id.*

35. Ervin et al., *supra* note 6, at 6.

36. John E. Losey et al., *Transgenic Pollen Harms Monarch Larvae*, 399 NATURE 214, 214 (1999).

37. Angelika Hilbeck et al., *Effects of Transgenic Bacillus Thuringiensis Corn-Fed Prey on Mortality and Development Time of Immature Chrysoperla Carnea (Neuroptera: Chrysopidae)*, 27(2) ENVT'L ENTOMOLOGY 480, 484 (1998).

were similarly free from Bt.[38] Hence, the authors conclude, the difference in mortality of lacewings is primarily due to Bt corn.[39]

It is worth mentioning here that the prediction of laboratory studies regarding the effects on non-target species might be different from the situation in the natural environment.[40] For example, if, in reality, non-targets are not exposed to Bt toxins, one certainly could argue that the risk of Bt crops on non-target species is actually low. However, a caveat given by the Ecological Society of America (ESA) might be worth considering: "if a Bt toxin kills pest insects, it also has the potential to kill other insects."[41] This potential should be taken into account if one considers whether the release of GMOs can only proceed with caution.

D. EFFECTS ON SOIL ECOLOGY

GM crops are also believed to have a significant impact on soil ecology. The impact may also occur from the significant use of Bt crops. A study by Saxena et al., for example, has observed that toxins in Bt crops persist in the soil for 234 days, allowing the toxins to keep their insecticidal characteristics and, thus, preventing them from being degraded by soil microbes.[42] The accumulation of toxins, which could be released into the soil as farmers incorporate plant material into the ground after harvest, has the potential to create serious environmental problems in the future.

From a legal perspective, questions arise from the discussions concerning the possible impact of GMOs in terms of what liability rules can be used for the damage caused by GMOs and who should be held liable when that damage occurs. These questions will be discussed in the following sections. Economic analysis will also be provided along with the discussions related to legal liability rules.

III. TYPES OF LIABILITY

A. THE CHOICE OF LIABILITY: EXPLORING LIABILITY FOR GMOS

The choice of liability for damage caused by GMOs has been dealt with differently from one country to another. Some countries, such as Germany, Austria, or Switzerland, have specific statutory provisions that establish strict

38. *Id.* at 484-85.

39. *Id.* at 485.

40. Wolfenbarger & Phifer, *supra* note 2, at 2089.

41. A.A. Snow et al., *Genetically Engineered Organisms and the Environment: Current Status and Recommendations*, 15(2) ECOLOGICAL APPLICATIONS 377, 393 (2005).

42. Deepak Saxena et al., *Insecticidal Toxin in Root Exudates from Bt Corn*, 402 NATURE 480, 480 (1999). The authors, however, have conducted other research, which, as quoted in Andow & Zwahlen, observes that the toxins can persist in the soil for at least 365 days. *See* Andow & Zwahlen, *supra* note 17, at 199.

liability for damage caused by GMOs.[43] Other countries might have no such specific provisions concerning GMO liability.[44]

Some scholars argue that a specific law on GMO liability is indeed unnecessary given the potential benefits, as well as the nature of GMOs. Bergkamp, for example, argues that concerns about environmental impacts of GMOs have been triggered by the fear of the unknown and unforeseeable risks of GMOs, which reflects emotion rather than rational reasoning.[45] From this point of view, the author not only rejects the idea of singling out GMOs and biotechnology for a specific liability or compensation system, but also sees no justification to treat biotechnology as dangerous activity subject to strict liability.[46] Whether or not a specific liability regime should be applied for GMOs, in our opinion, depends on the question of whether GMOs and their impacts are unique, as compared to non-GM counterparts, so as to warrant the establishment of a specific statutory liability. It is, unfortunately, beyond the scope of this paper to analyze the uniqueness of GMOs and their possible impacts. However, it could be argued that in the absence of a specific GMO liability regime, general civil liability will be applied to GMO cases. In this regard, liability for damage caused by GMOs will be established according to negligence rule, strict liability, or other forms of liability rules, be it trespass or nuisance. We will in this section first explore the possibilities of using legal rules with respect to negligence, strict liability, trespass and nuisance to damage caused by GMOs and will in that respect especially pay attention to the legal rules that were in practice used in case law. Next we address the available legal rules, and more particularly, the choice between strict liability and negligence, from an economic perspective (2) and then turn to environmental liability (3). We then address the possibility of applying the product liability regime to liability caused by GMOs (4), again using the perspective of economic analysis of law. Finally, we examine to what extent the regulatory regime with respect to GMOs and, more particularly, prior safety regulation, will have an influence on liability (5).

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43. *See* Vanessa Wilcox, *Summaries of the Country Reports*, 24 TORT AND INS. LAW, ECONOMIC LOSS CAUSED BY GENETICALLY MODIFIED ORGANISMS 19, 19, 30, 49 (Bernhard A. Koch ed., 2008) (summarizing the reports of the application of liability and compensation schemes in several European countries).

44. From a report of Intergovernmental Committee for the Cartagena Protocol on Biosafety, for example, one may immediately see that not all countries have provisions on liability specifically directed for GMOs. The report shows that when no such provisions exists, the issue of liability might be addressed through general civil liability system. See: Intergovernmental Committee for the Cartagena Protocol on Biosafety, "Liability and Redress (Article 27): Compilation of Information on National, Regional, and International Measures and Agreements in the Field of Liability and Redress for Damage Resulting from the Transboundary Movements of Living Modified Organism", UNEP/CBD/ICCP/3/INF/1, 2 April 2002.

45. Lucas Bergkamp, *Allocating Unknown Risk: Liability for Environmental Damages Caused by Deliberately Released Genetically Modified Organisms* 29 (Social Science Research Network, Working Paper, 2000), *available at* http://ssrn.com/abstract=223068.

46. *Id.* at 29. Bergkamp argues that although it is unlikely for the release of GMOs undertaken in compliance with regulations and conditions prior to authorization, activities involving GMOs conducted in an irresponsible way could be subject to strict liability, since they may pose significant risks. *See id.* at 25.

1. Negligence Rule

If genes from GM crops drift into a neighboring field and cross-pollinate with non-GM relatives, one could expect that damage to that neighboring field will follow. Damage might also occur when GM crops designed to contain Bt toxins increase the development of pesticide-resistance in pests or kill non-target insects. If such damage arises, the first type of liability that can be assigned is negligence.

Under the negligence rule, a plaintiff injured by GMO contamination may claim that the neighboring farmers planting GM crops, or the seed company, are liable for the resulting damage. In this case, the plaintiff has to prove that the defendants owe a duty of care, for example to take any precaution to prevent the damage from occurring, and that they have breached that duty by unreasonable conduct. In addition, the plaintiff also bears the burden of proving cause-in-fact (causation) and the proximate cause, as well as the damage suffered.[47]

In the *StarLink* litigation,[48] the plaintiffs argued that the defendant, i.e. Aventis, had breached the duty of care due to its failure to comply with the regulatory standard of care.[49] The plaintiff also alleged that prior to the 2000 growing season, the defendant had instructed its seed representatives that it was unnecessary to advise the farmers to segregate *StarLink* corn and to create a buffer zone.[50] This breach of the duty of care is alleged to have caused the damage to the plaintiffs. This damage consisted of the widespread contamination of *StarLink* corn into food products, leading to various economic losses in the corn market

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47. Kershen, *supra* note 5, at 458.

48. The StarLink case was triggered by the finding of Bt genes, *i.e.*, the so-called Cry9C genes, in corn-based products for human consumption. The genes supposedly originated from Aventis's StarLink, a GM corn specifically designated for animal feed. Due to its potential health impacts, GM crops containing the Cry9C have been rejected for human consumption by the U.S. authority. This finding induced several corn farmers, on behalf of nationwide corn farmers, to bring actions against Aventis, i.e. the manufacturer of StarLink corn. The farmers alleged that the manufacturer has disseminated a product that contaminated the corn supply, increasing farming costs and depressing corn prices. *See In re* StarLink Corn Prod. Liab. Litig., 212 F. Supp. 2d 828, 828-829 (N.D. Ill. 2002). For a brief introduction to this case, see Lara Khoury & Stuart Smyth, *Reasonable Foreseeability and Liability in Relation to Genetically Modified Organisms,* 27 BULL. SCI. TECH. & SOC'Y 215, 222 (2007); *see also* Stuart Smyth et al., *Liabilities and Economics of Transgenic Crops*, 20 NATURE BIOTECHNOLOGY 537, 537-38 (2002).

49. Such a standard includes mandatory segregation methods to prevent StarLink from commingling with other corn, and a "buffer zone" around StarLink corn crops to prevent cross-pollination with non-StarLink corn plants. In addition, the EPA has required Aventis to inform farmers of the EPA's requirements for the planting, cultivation and use of StarLink; to instruct farmers growing StarLink how to store and dispose of the StarLink seeds, seed bags, and plant detritus; to ensure that all farmers purchasing StarLink seeds signed the Grower Agreement, a contract binding the growers to these requirements before permitting them to grow StarLink corn; to inform growers at the time of StarLink seed corn sales of the need to direct StarLink harvest to domestic feed and industrial non-food uses only; to write to growers prior to planting, in order to remind them of the domestic and industrial use requirements for StarLink corn; and to conduct a statistically sound follow up survey of growers to monitor compliance with the Grower Agreement. *StarLink*, 212 F. Supp. 2d at 834-35.

50. *Id.* at 835.

due to the fear of such contamination.[51]

2. Strict Liability

Strict liability may be used by the plaintiffs for damage resulting from GMOs. Under strict liability, the plaintiffs do not need to prove the defendants' fault. However, to be able to rely on strict liability, the plaintiffs still have to prove that the damaging activity is abnormally dangerous. In order for an activity to qualify as dangerous, scholars frequently refer to the Restatement (Second) of Torts § 520 (1977), which provides several factors in determining whether an activity is abnormally dangerous. These factors are: existence of a high degree of risk of some harm; the likelihood that the resulting harm will be great; the inability to eliminate the risk by the exercise of reasonable care; the extent to which the activity is not a matter of common usage; the inappropriateness of the activity to the place where it is carried on; and the extent to which the activity's value is outweighed by the danger it imposes.

In *Hoffman v. Monsanto*,[52] the plaintiffs resorted to strict liability, in addition to the negligence rule, trespass, and nuisance, in seeking compensation due to the alleged contamination, or potential contamination, from GM canola. In this case, the plaintiffs claimed that the defendants were liable for having engaged in a "non-natural use of land," and allowing "the escape of something likely to do mischief and damage."[53]

One may argue that by using the phrase "unnatural use of land" that the plaintiffs were actually attempting to meet one of the factors mentioned above, in order to qualify the defendants' activity as an abnormally dangerous activity. In this regard, the defendants' activity, namely releasing GM canola either for testing or commercial purposes, should be proven to be an uncommon usage of land. This was, however, not the case in *Hoffman v. Monsanto*. In this case, there was no test of whether the defendants' activity was an unnatural use of land. As a result, the only way of determining the activity as abnormally dangerous was by

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51. *Id.* at 833, 835.

52. Plaintiffs were organic farmers who brought a class action, on behalf of organic farmers in Saskatchewan, against seed manufacturers of GM canola, *i.e.* Monsanto Canada Inc. and Bayer Cropscience Inc. The plaintiffs sought damages based on the allegation that "adventitious presence" of GM canola in fields of organic grain farmers, or potential for it, made it impossible for farmers to guarantee that canola grown as organic did not contain traces of GM canola seed, with the result that canola could not be grown for the organic market. In addition, the plaintiffs also argued that even if organic farmers are not growing canola, they suffer contamination of their fields due to the prevalence of Roundup Ready canola or Liberty Link canola "volunteers" growing on their land. In this regard, the plaintiffs sued for the past and future cleanup costs resulting from contamination. Finally, the plaintiffs claimed that the abandonment of an "identity preservation program" (IPP) that had been implemented by the defendants in 1995–96 to ensure the segregation GM canola for the purposes of export, has resulted in the loss of the European market for all Canadian canola. Hoffman v. Monsanto Canada Inc., 2005 SKQB 225, 264 Sask. R. 1, paras. 19-21 (Can. Sask. Q.B.).

53. *Id.* at para. 89.

considering the question of whether GM canola was a dangerous substance. Apparently, the plaintiffs failed to convince the court in this matter. The court stated accordingly:

> The point here simply is that the plaintiffs' theory, in general, does not rely upon proving that GM canola is inherently harmful or dangerous. Indeed, any allegation that GM canola is inherently harmful or dangerous in any respect, or at least that any possible or potential inherently harmful quality was known to the defendants at the time that GM canola was commercially introduced in Canada, would seem to be inconsistent with the express pleading of the AAFC decision documents.[54]

The ruling of *Hoffman v. Monsanto* above seems to confirm some of the authors' doubt on the ability of the plaintiff to qualify the planting or release of GM crops, for example, as an abnormally dangerous activity. In this regard, some authors also believe that unless used inappropriately, GMOs pose no higher risks than their non-GM counterparts.[55] In addition, when a plaintiff is an organic farmer and if organic farming is considered an activity with abnormally sensitive character, the plaintiff will not succeed in establishing liability, because, according to the Restatement (Second) of Torts § 524 (1977), strict liability is not applicable if the harm suffered by the plaintiff would not occur but for the abnormally sensitive character of the plaintiff's activity.[56]

Such difficulties in proving that planting GM crops is abnormally dangerous will certainly be lessened if a country has statutorily determined that strict liability is applicable for damage caused by GMOs. In this case, one may argue that such a country has statutorily considered planting GM crops or releasing GMOs into the environment, for example, is a dangerous activity.

3. Trespass

Liability for damage caused by GMOs may also be established according to the law of trespass, namely an interference of one's exclusive possession of land.[57] According to de Beer, the law of trespass requires a direct and physical interference, in the sense that it was the physical conduct of the defendant that has directly invaded the plaintiff's property. With respect to the requirement of physical interference, de Beer argues that genetic engineering changes not only

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54. *Id.* at para. 23. Agriculture and Agri-Food Canada (AAFC) has determined that GM canola "does not present altered environmental interactions when compared to existing commercialized canola varieties in Canada, and is considered substantially equivalent to canola currently approved as livestock feed." *Id.* at para. 16.

55. *See* Margaret Rosso Grossman, *Biotechnology, Property Rights and the Environment*, 50 AM. J. COMP. L. 215, 238 (2002).

56. Kershen, *supra* note 5, at 457.

57. Stephanie E. Cox, *Genetically Modified Organisms: Who Should Pay the Price for Pollen Drift Contamination?*, 13 DRAKE J. AGRIC. L. 401, 410 (2008).

the physical characteristics of an organism, but also the physical appearance and structure of the DNA molecule.[58] By referring to the doctrine of cyber trespass, de Beer concludes that if cyber trespass is actionable, then gene trespass should also be actionable.[59]

With respect to the issue of directness, one may suggest that natural forces play a significant role in the contamination by GMOs. In this respect, a question arises as to whether planting or releasing GM crops into the environment could meet the directness requirement. In the law of trespass, directness means that the interference flows from the defendant's act without the intervention of other factors. In *Hoffman v. Monsanto*, Judge Smith argued that the adventitious presence of GM crops in non-GM crops and on the organic farmers' field does not constitute a trespass because "it is clear that much more than 'natural and inevitable forces' must intervene between merely marketing GM canola and its arrival on the plaintiffs' land."[60] Hence, natural forces may help the defendant escape liability for the trespassing genes. However, such an argument has been challenged by de Beer, arguing that Judge Smith has failed to distinguish between merely marketing GM crops and controlling the crops until natural forces take over. De Beer points to various rulings on trespass that have concluded that natural forces, such as wind, do not undermine a finding on directness.[61] Based on these rulings, the author argues that the issue of directness in the law of trespass corresponds to the question of whether the consequences of the defendant's act are natural and inevitable.[62] Following de Beer's argument, one could thus argue that so long as the trespassing genes could be proven a natural and inevitable consequence of the defendant's act, such as planting or releasing GM crops, then the law of trespass is also applicable for gene contamination.

The law of trespass also requires intentional conduct by the defendant. In this regard, intentional conduct does not necessarily mean that the defendant has intended to create damage to the plaintiff. Rather, merely an intentional act that directly interferes with the plaintiff's property has already constituted trespass. In

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58. Jeremy de Beer, *Biotrespass*, 27 BULL. SCI. TECH. & SOC'Y 287, 291 (2007).

59. *Id.* at 292. Other authors consider the physical interference of GM crops similar to trespass by airborne pollutants or particulates, such as drifts from aerial spray of pesticides. *See* Amelia P. Nelson, *Legal Liability in the Wake of StarLink™: Who Pays in the End?*, 7 DRAKE J. AGRIC. L. 241, 258 (2002); *see also* Grossman, *supra* note 55, at 235-36. In addition, trespassing genes may also be analogous to a trespass of chattels. As a consequence of equalizing a trespass of genes with cattle trespass, strict liability should be applied to the trespass of genes. This is because, as concluded by Black & Wishart, cattle trespass contains several principles, namely: 1) because of their self-willed, self-replicating nature, and the tendency to escape the control of their owners and to create harm, living cattle require special consideration by the law; 2) those who exercise control over and derive benefits from living cattle bear the responsibility to prevent the escape of that cattle; and 3) if the cattle eventually escape and trespass on one's property, the keeper of the cattle should compensate the victim on the basis of strict liability. *See* Katie Black & James Wishart, *Containing the GMO Genie: Cattle Trespass and the Rights and Responsibilities of Biotechnology Owners*, 46 OSGOODE HALL L.J. 397, 415 (2008).

60. *Hoffman*, 2005 SKQB at para. 131.

61. Jeremy de Beer, *supra* note 58, at 292.

62. *Id.* at 294.

this respect, de Beer argues that there is no need to consider the defendant's fault once it is proven that the defendant intended to act in a way that interferes with the plaintiff's property.[63]

Another requirement in the law of trespass corresponds to the question of whether damage should be proven to establish liability. In this regard, de Beer observes that in the common law system, a trespass to land does not require the proof of damage, while a trespass to chattel might require such proof.[64] Accordingly, de Beer suggests that if the case in question involves a spill of seeds or plants onto the plaintiff's land, then trespass to land will be more appropriate as a cause of action; while if the case involves the plaintiff's plants being cross-pollinated by genes from the defendant's GM plants, trespass to chattel is more appropriate.[65]

4. Nuisance

Another form of liability that can be used for damage caused by GMOs is nuisance. It may take form either as private nuisance or public nuisance. A private nuisance is an invasion of one's interest in the private use and enjoyment of land. In this regard, a farmer suffering the contamination of GM crops may claim that the contamination constitutes an invasion of his/her interest in the enjoyment of land.[66]

A private nuisance could be brought in terms of intentional or negligent nuisance. In an intentional nuisance, the plaintiff must prove that the defendant has not taken any action to prevent the damage. In this regard, the plaintiff has to prove, for instance, that the defendant has failed to take any precaution to prevent the contamination of GMOs. In a negligent nuisance, the plaintiff has to prove that the defendant's act was unreasonable.[67]

Unlike private nuisance, which closely relates to the use or enjoyment of land, public nuisance can be brought against damage to the common rights of the general public. When public nuisance is used, the plaintiff must prove that the defendant's act was unreasonable. To determine whether a defendant's conduct is unreasonable, authors usually refer to several factors specified in the Restatement (Second) of Torts § 821B, including:[68]

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63. *Id.* De Beer also argues that unlike the negligence rule, the defendant cannot escape liability by claiming that he/she has taken a reasonable level of care to avoid the damage. In addition, unlike the law of nuisance, the law of trespass does not require an inquiry into the reasonableness of the defendant's interference with the plaintiff's property. *Id.* at 290.

64. De Beer finds that with respect to a trespass to chattel, the American courts require the proof of actual or potential harm suffered by the plaintiff, while the British courts seem to be of the opinion that the harm is not an element of a trespass to chattel. Canadian courts seem to be ambiguous in this matter. *Id.* at 289.

65. *Id.* at 290.

66. Cox, *supra* note 57, at 409.

67. Grossman, *supra* note 55, at 233.

68. Nelson, *supra* note 59, at 259.

- Whether the conduct involves a sufficient interference with the public health, safety, peace, comfort, or convenience;
- Whether the conduct is proscribed by a statute, ordinance, or administrative regulation
- Whether the conduct is of a continuing nature or has produced a permanent or long-lasting impact.

Private individuals that use public nuisance must be able to establish that the defendant's act interfered with the common rights of community and that the damage suffered by these private individuals is different from the damage suffered by the general public. In the *StarLink* litigation, the court upheld the public nuisance claim based on two related reasons. On the one hand, the court found that "contamination of the food supply implicates health, safety, comfort and convenience," and hence, the plaintiffs satisfied the requirement that the defendant's act interfered with the common rights of community.[69] On the other hand, the court also found that the damage suffered by the plaintiffs, i.e. commercial corn farmers, was different from the damage suffered by the general public.[70] In this regard, the court argued that "while the general public has a right to safe food, plaintiffs depend on the integrity of the corn supply for their livelihood."[71] Thus, the plaintiffs were affected differently than the general public.

The discussions above indicate that general tort law may be a quite effective means of addressing the issue of liability for damage caused by GMOs. However, one may still argue that compared to other types of liability rules, strict liability is preferable. A law and economics analysis in the following section will answer whether this is the case.

B. ECONOMIC CRITERIA FOR STRICT LIABILITY

Economists use classic cost/benefit analysis to determine what the level of care is that will lead to a minimization of the social costs of accidents. Not surprisingly, this can be found where the marginal costs of care-taking equal the marginal benefits in accident reduction. Indeed, since care-taking has its price as well, a legal rule should not give incentives to avoid every possible accident that could occur, but only accidents that could be avoided by investments in care, of which the marginal costs are lower than or equal to the marginal benefits in accident reduction. It might well be that extremely high care could additionally contribute to a reduction in the accident risk, but the marginal costs of care-taking in that case might be much higher than the additional benefit in accident reduction. Investments in care would, in that case, be inefficient and scarce

69. *In re* StarLink Corn Prod. Liab. Litig., 212 F. Supp. 2d 828, 848 (N.D. Ill. 2002).
70. *Id.*
71. *Id.*

resources would be spoiled.[72] These levels of care where marginal costs of care-taking equal marginal benefits in accident reduction are referred to in the literature as the optimal or efficient level of care.[73] We will now first address optimal liability rules in a unilateral case. In the unilateral accident situation we refer to the case where only one party (referred to as the injurer or tortfeasor) can influence the accident risk.

Before addressing which liability regime may be giving appropriate incentives for accident reduction we should first stress that traditional economic analysis of law points at the fact that when transaction costs are zero an optimal allocation (e.g., following the optimal care level) would always follow, no matter what the legal rule holds. This constitutes an application of the so-called Coase theorem.[74] This Coase theorem is especially important in a situation where a contractual relationship between injurer and victim exists. Hence, we will address the importance of the Coase theorem when referring to product liability below (4). However, when the victim is a third party (for example, a neighboring farmer who had no contractual relationship with the manufacturer of GMOs) the Coase theorem will not be applicable. In that case, a legal regime needs to give incentives for care-taking and hence this distinction between the unilateral case (where only the injurer influences the accident risk) and the bilateral case (where both parties influence the accident risk) becomes important again.

Looking at a unilateral accident situation, one can state that two legal rules that would give the injurer incentives for taking optimal care. If there were no liability at all, clearly the injurer would have no incentive for care-taking; therefore in a no-liability situation the externality will not be internalized and an inefficient outcome will follow. If a negligence rule is adopted, the injurer will take optimal care, provided the due care required in the legal system is equal to the optimal care as resulting from a marginal cost/marginal benefits weighing.[75] This can be easily understood if the judicial system sets the due care standard correctly; the injurer can avoid liability by taking due care. Thus, he will have to take care to avoid the accident, but if he does so, he can avoid paying the expected damage. Of course, the injurer could take more care than the legal system requires him to do under a negligence rule, but he will have no incentive to do so since he can already escape liability by following the due care standard. The injurer could also spend less on care than the legal system requires him to. In that case he will have lower costs of care-taking, but he will have to pay damages in case an accident

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72. This finding only holds in a risk neutral setting. In case of risk aversion higher investments in care might well be efficient since a reduction of accident risk will in that case also remove the disutility of risk from a risk-averse person.

73. *See* William M. Landes & Richard A. Posner, *The Positive Economic Theory of Tort Law*, 15 GA. L. REV. 851, 870 (1981); *see also* A. MITCHELL POLINSKY, AN INTRODUCTION TO LAW AND ECONOMICS 7 (1983).

74. *See generally* R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960).

75. Steven Shavell, *Strict Liability Versus Negligence*, 9 J. LEGAL STUD. 1, 21 (1980); Guido Calabresi, *Optimal Deterrence and Accidents*, 84 YALE L.J. 656, 658 (1975).

occurs. Since the optimal care standard was defined as exactly that level of care where the marginal costs of care equal the marginal benefits in accident reduction, taking less than the due care standard will not be efficient for the individual injurer since it will increase his total expected costs. Thus, a negligence rule will lead to an efficient outcome as long as the legal system defines due care as equal to the optimal care of the model.[76]

Also, a strict liability rule will lead to the optimum in a case where only one party can influence the accident risk. The reason is quite straightforward. A strict liability rule basically states that the injurer has to compensate in any case no matter the level of care he took. It is sometimes argued that this will lead the injurer to take excessive precautions or to take no care at all since he is liable anyway. Neither of these statements seems true. By making the injurer strictly liable, the social decision is in fact shifted to the injurer. In a unilateral accident case it simply means that he has to bear all the social costs of accidents, i.e. his own costs of care-taking and the expected damage.[77] Therefore, he will take exactly the same decision, i.e. to minimize his total expected accident costs. This can be reached at the optimal care level. Therefore, the injurer will take optimal care since this is the way to minimize his total expected costs. Spending more on care would increase his costs of care-taking inefficiently and spending less on care would increase the expected damage inefficiently.

In addition, strict liability is more preferable than the negligence rule when one takes into account the activity level. Under the negligence rule, the injurer will escape liability as long as he takes the optimal level of care. As a result, so long as the injurer maintains the optimal level of care, he does not have to take into account the optimal level of his activity. This means that from society's point of view, a number of activities might be excessively inefficient. The situation will be different under strict liability. Since the injurer will be liable whenever the accident occurs, the injurer will pay adequate attention not only to the optimal level of precaution, but also to the optimal level of activity.[78]

Theoretically, the risk of an accident taking place depends not only on the level of precaution, but also on the number of activities.[79] Hence, since strict liability will induce the injurer to take into account both optimal precaution and activity level, we could argue that strict liability is superior to the negligence rule.

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76. For a recent discussion of the economics of strict liability versus negligence, see Hans-Bernd Schäfer & Frank Müller-Langer, *Efficient Liability Rules*, *in* TORT LAW AND ECONOMICS 3 (Michael Faure ed., 2009).

77. POLINSKY, *supra* note 73, at 39; Shavell, *supra* note 75, at 11.

78. Louis Kaplow & Steven Shavell, *Economic Analysis of Law* 4 (Nat'l Bureau of Econ. Res., Working Paper No. 6960, 1999).

79. Faure & Skogh have given an example about the risk of having a traffic accident, which depends not only on the care that the driver takes, but also on the number of kilometres driven in a certain period of time. Here, the authors also conclude that in terms of providing incentives to take optimal activity levels, only strict liability will be efficient. *See* MICHAEL FAURE & GORAN SKOGH, THE ECONOMIC ANALYSIS OF ENVIRONMENTAL POLICY AND LAW: AN INTRODUCTION 252-53 (2003).

How does one, in sum, apply the economic arguments in favor of strict liability to the case of damage caused by GMOs?

The first question to be answered is whether the handling of GMOs should be considered as a unilateral accident, being an accident where only the injurer can influence the accident risk. If that were the case, we concluded that the economic model predicts that the advantage of the strict liability rule is that it will provide the injurer optimal incentives for care.[80] If in this particular case, the victim cannot influence the accident risk, strict liability would be the first and best solution, by providing the operator of the GMO optimal incentives to reduce the risk that GMO crops would cause damage to third parties.

The question, however, arises whether damage caused to a third party[81] by GMO crops is always a truly unilateral accident. Depending upon the factual circumstances (which can of course significantly vary) some may argue that one could imagine circumstances where potential victims could also take measures to prevent the damage. If that would be the case, one could argue that GMO damage becomes a bilateral risk in which the potential victim could also take efficient measures to prevent the risk. However, one could still argue that the influence of the operator of the GMO is probably still far more important than the influence of the victim. If that is the case, the outcome does not change and the strict liability rule remains warranted to give the operator of the GMO optimal incentives to take preventive measures. This clearly assumes that the operator who handles the GMO is in the best position to prevent the risk. However, as will be mentioned below, in this bilateral case, it remains important that a defense should be added to the strict liability rule to give victims incentives for prevention as well. However, if it would appear from the factual situation that it is as important to provide victims with incentives to prevent the risk, as it is to give similar incentives to the operator who handles the GMO, a negligence rule would be optimal.

Hence, GMO damage does not seem to be comparable with a classic environmental case. In the latter case, it is often argued that these are typical unilateral cases, where most of the influence of the accident risk comes from the potential polluter. Therefore, most argue in favor of a clear strict liability rule since the victim can usually do less than the potential polluter to avoid the risk. However, since potential victims in the GMO case may be professionals as well, the same line of reasoning does not apply. If in fact it appears that the influence of both the potential victim and the operator who handles the GMOs is equally important, a negligence rule might in fact be optimal.[82]

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80. Also, it would provide optimal incentives to take an efficient activity level. *See* Shavell, *supra* note 75, at 1 (on the importance of the activity level).

81. Remember that with a third party we refer to the victim not standing in a contractual relationship with the injurer (GMO producer), since in that case the Coase theorem may be applicable.

82. The economic reason is that only negligence also provides incentives to the victim to adopt an optimal

From the explanation above, it appears that whether GMO liability cases are of a unilateral or a bilateral nature depends upon the factual situation. One could certainly argue that cross-pollination from GM crops to non-GM crops constitutes a unilateral case. This is because if organic or conventional farmers should also prevent the cross-pollination, they should change their usual practices and, hence, incur high costs.[83] Under this situation, following the Coase theorem we presented above, if transaction costs between organic farmers and farmers planting GM crops are low, they may bargain to determine who is in a better position (i.e. has the ability to more cheaply negotiate) to prevent the pollination. However, if transaction costs are high, a liability rule more suitable for the unilateral case should apply. In this regard, strict liability may be better than a negligence rule.[84] Transaction costs will certainly be high in the situation where, for example, damage does not consist of admixtures but of damage to a third party not in agriculture at all.

Moreover, another argument in favor of strict liability is related to the fact that the negligence rule works efficiently only if the judge is able to set the due care standard required in the legal system efficiently. However, in reality this may require very high information costs and judges may have difficulties adequately balancing the marginal costs of taking additional preventive measures versus the marginal benefits in further reducing the accident risk. The advantage of strict liability is that in that particular case, all information costs are shifted to the injurer. Under strict liability it is indeed the injurer who balances costs and benefits of prevention costs versus the potential damage. Hence, in cases where one would assume that injurers are better able than judges to adequately perform the cost-benefit analysis required to set the due care level this would be yet another important argument in favor of strict liability. Of course the latter argument may once more provide a strong case for strict liability when damage results from the use of GMOs. Indeed, for the judge to efficiently set a due care standard, high information costs would be involved. Given the highly technical nature of the risk, it may be impossible for the judiciary to set care standards adequately.[85] Under strict liability, it is the producer of GMO who will balance

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activity level.

83. One commentator notes that if organic or conventional farmers are forced to prevent gene contamination, they may have to abandon their seed-saving practices and, given resistance of the hybrids, use more toxic herbicides. Preston, *supra* note 14, at 1159.

84. Another reason for applying strict liability is the nonreciprocal nature of damage possibly suffered by the organic or conventional farmers. In this case, a farmer who plants GM crops gains benefits from his crops, while at the same time exposing his neighbor to a risk to which he is not subjected, e.g. the risk of losing organic certification. *See* A. Bryan Endres, *"GMO:" Genetically Modified Organism or Gigantic Monetary Obligation? The Liability Schemes for GMO Damage in the United States and the European Union*, 22 LOY. L.A. INT'L & COMP. L. REV. 453, 491 (2000). A rationale behind this argument is probably related to the issue of the distribution of risk and benefit, in which those who gain benefits, while at the same time subjecting others to risks, should pay the damages if those risks materialize.

85. One has to balance this somewhat because the judge is of course aided in this process of weighing costs

cost and benefits and will subsequently choose the efficient care level. If producers are better informed than the judiciary on the optimal care necessary to reduce the risk (which is very likely in the case of GMO risks) this constitutes yet another argument in favor of strict liability.

Above we indicated that a second advantage of strict liability is that it will also provide incentives to adopt a correct activity level. This might also mean that the application of strict liability to GMO cases will reduce the number of activities involving GMOs. Whether or not this is a desirable result will depend largely on the benefits of GMOs relative to possible costs resulting from the commercial release of GMOs.

C. ENVIRONMENTAL LIABILITY

If one now turns away from the more traditional tort case (where a third party victim suffers loss resulting from the GMO) and assumes that damage is caused to the environment as such, the question arises how that affects the choice between strict liability and negligence. An important difference between the classic tort case and the case where GMOs cause damage to the environment as such, is that environmental harm usually makes the accident situation unilateral. There is indeed very little that the environment as such could do to prevent the accident. As we mentioned above, it is argued in economic literature that in a unilateral accident model (where only the behavior of the injurer influences the accident risk) strict liability will be efficient since it induces the injurer to adopt an efficient activity level and optimal care. Therefore, it has been argued that there seems to be an economic rationale behind the tendency in case law and in many environmental statutes in legal systems to introduce strict liability for environmental damage; since the victim cannot influence the accident risk, strict liability will be the best solution to give the potential polluter optimal incentives for accident reduction.[86] A few important nuances have been formulated in the literature in this respect: strict liability (for environmental harm) assumes that the judge has accurate information on the amount of the damage. If courts err in assessing damages, strict liability, as Cooter showed, will lead to under-deterrence.[87] Strict liability is also only efficient if the injurer is always held to fully pay for the consequences of the accident. If the injurer were insolvent or if the judge were to underestimate the amount of the damage, a negligence rule would be preferred. This is the case, provided that the judge could at least

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and benefits by the regulator. To some extent, the regulator took over this process and set efficient regulatory standards on which the judge can rely in a negligence case. For further details see Michael Faure, *Economic Analysis of Tort and Regulatory Law*, *in* TORT AND REGULATORY LAW 399 (Willem H. van Boom, Meinhard Lukas & Christa Kissling, eds., 2007).

86. For a detailed analysis see the contributions in DETERRENCE, INSURABILITY, AND COMPENSATION IN ENVIRONMENTAL LIABILITY: FUTURE DEVELOPMENTS IN THE EUROPEAN UNION (Michael Faure ed., 2003).

87. *See* Robert Cooter, *Prices and Sanctions*, 84 COLUM. L. REV. 1523, 1540 (1984).

adequately fix the optimal level of care, even if there was uncertainty concerning the precise amount of the damage.[88] This, therefore, leads to a balanced conclusion as far as the optimal liability rule is concerned for environmental damage caused by GMOs; given the unilateral nature of the damage, strict liability may have a preference. This, however, only holds if the injurers are not insolvent and if the courts can assess the damage correctly. Also, Trebilcock pointed at the fact that (in environmental, but also in other liability areas) strict liability may have undesirable effects if it is combined with other features such as shifting the burden of proof, joint and several liability and high (punitive) damages for (non-pecuniary) losses.[89] The reason why strict liability regimes in the U.S., like CERCLA, also referred to as Superfund, are regarded as "crushing" is not so much because of the strict liability itself, but because of the combination of joint and several liability together with the retrospective nature in the case of Superfund liability.[90] Therefore the final judgment on the efficiency of strict liability for environmental harm may depend upon these other issues such as causation and the magnitude of damages awarded.[91] Interestingly, recent empirical evidence has shown that environmental liability regimes do indeed have a positive influence on the incentives of potential polluters to take additional preventive measures.[92]

D. PRODUCT LIABILITY

In addition to the liability rules discussed in the previous section, product liability may also be used by the victims who suffer damage from the release or planting of GMOs. In fact, as one author predicts, product liability is among the most likely biotechnology causes of action, ranging from claims for allergenicity, toxicity, contamination and other damages.[93]

In order to succeed in a product liability claim, the plaintiff must be able to establish several elements, namely that the defendant has sold and been engaged in the selling of the damaging product, that the product was defective, that the defect was unreasonably dangerous, that the product reached the user without substantial change, and that the product was the proximate cause of the plaintiff's

88. *Id.* at 1542.

89. *See* Michael J. Trebilcock, *The Social Insurance-Deterrence Dilemma of Modern North American Tort Law: A Canadian Perspective on the Liability Insurance Crisis*, 24 SAN DIEGO L. REV. 929, 929-30 (1987).

90. *See* James Boyd, *A Market-Based Analysis of Financial Insurance Issues Associated with U.S. Natural Resource Damage Liability*, *in* DETERRENCE, INSURABILITY, AND COMPENSATION IN ENVIRONMENTAL LIABILITY: FUTURE DEVELOPMENTS IN THE EUROPEAN UNION 258 (Michael Faure ed., 2003).

91. *See generally* Trebilcock, *supra* note 89.

92. For a discussion of this literature see Michael Faure, *Environmental Liability*, *in* TORT LAW AND ECONOMICS 247, 252-253 (Michael Faure ed., 2009).

93. Gregory N. Mandel, *The Future of Biotechnology Litigation and Adjudication*, 23 PACE ENVTL. L. REV. 83, 95 (2006).

injury.[94] In our opinion, from those five elements, the most important element that must be established is that the product was defective. For the GMO case, this means that a GM product was defective, either in terms of a manufacturing defect or a design defect. A manufacturing defect occurs when a particular unit of product deviates from other units in such a way that imposes harm to the user. Unlike a manufacturing defect, a design defect occurs when a specific product unit fits its intended design, but the design itself causes the product to be unsafe. In addition to manufacturing and design defects, a defect could also be indicated by the failure to warn or to provide adequate warning. A producer of a dangerous product, when he/she knows or should have known the risks of his/her product, bears the responsibility to give adequate directions or warning to prevent such risks from occurring. A failure to warn or an inadequate warning gives rise to the producer's liability.[95]

Compared to the manufacturing defect, the design defect and inadequate warning are more likely to indicate the defect of GMOs. With respect to the design defect, Moltalbano argues that the very nature of a GM plant, in this case GM bentgrass designed to have resistance to herbicides, has the potential to create impacts, such as cross-hybridization with non-GM grass, which make the GM grass unreasonably dangerous, and hence, indicate a design defect.[96] Of course, one may also argue that many potential impacts do not result from the GM plant design, but from the segregation practices and inappropriate use of the GM plant.[97] In our opinion, the fact that GM crops require approval from state agencies implies that the potential harmful impacts of the currently marketed GMOs do not necessarily mean that the products contain a design defect. Regulatory agencies consider such harmful impacts as normal, and therefore, capable of being averted with various preventive measures and adequate instructions. Consequently, a defect might be established only when the producers fail to provide adequate instructions, directions, or warning of the potential impacts.

Another important issue in products liability corresponds to the question of whether a third party, being harmed by the product, can sue the producer on the grounds of product liability. This is apparent in the *StarLink* litigation, which in essence is product liability litigation. In that case, claims on the negligence rule, strict liability, trespass, and nuisance stemmed from an allegedly defective product of *StarLink* corn. However, each of the plaintiffs was an organic farmer who did not purchase or use the defendant's product. In addition, one of those plaintiffs also claimed under the Tennessee Consumer Protection Act (TCPA) that

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94. Roger A. McEowen, *Legal Issues Related to the Use and Ownership of Genetically Modified Organisms*, 43 WASHBURN L.J. 611, 625-26 (2004).

95. Brady L. Montalbano, *It's Not Easy Being Green–Holding Manufacturers of Genetically Modified Bentgrass Liable Under Strict Products Liability*, 14 PENN. ST. ENVTL. L. REV. 111, 122-23 (2005).

96. *Id.* at 123.

97. *In re* StarLink Corn Prod. Liab. Litig., 212 F. Supp. 2d 828, 837 (N.D. Ill. 2002).

the defendant was involved in a deceptive trade practice.[98] The defendant rejected the claim by arguing that the plaintiff had no consumer transaction with the defendant.[99] The court upheld the plaintiff's claim by arguing that the TCPA allows the third parties to bring a claim if they are harmed by the deceptive trade practices of the defendant.[100]

From the discussions above, it appears that product liability is a viable cause of action in the case of damage caused by GMOs. Consequently, the issue of product liability for damage caused by GMOs also merits a law and economics analysis. Product liability could be first analyzed from an economic perspective; it is a case whereby damage is caused to a party standing in a contractual relationship with the injurer, in this case the one producing, manufacturing, or delivering the GMOs. In that particular case of product liability it is important to look at the contractual situation. Subsequently, the fact that a particular product (that by hypothesis has used GMOs) has first been delivered to a purchaser has important consequences for the structure of the liability rule, even if damage would not be caused to the purchaser but to third parties. Economic analysis carefully distinguishes the various hypotheses that can be recognized in this respect.

1. Contractual Liability Based on the Coase Theorem

In the economic analysis of law, the Coase theorem plays an important role for analyzing efficient product liability rules. Applying the Coase theorem in a product liability setting means that if a purchaser of a product is fully informed of the possible defects and the product risk, he will always take into account the expected damage and add this to the market price to decide whether or not to purchase the product. The well-informed consumer will always take into account the full price of the product, which includes the expected damage.[101] In that case, the agreement on the distribution of risk might be reflected in the contract price. The price mechanism can have this signaling function to the consumer. If the market price reflects the expected damage, the consumer can know that the producer bears the accident risk. If, however, the market price only reflects the cost price of the product and not the expected damage the well-informed consumer would know that he bears the accident risk himself.[102]

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98. *Id.* at 851.

99. *Id.* at 851.

100. *Id.* at 852.

101. Walter Y. Oi, *The Economics of Product Safety*, 4 BELL J. ECON. & MGMT. SCI. 3, 5 (1973); Michael Adams, *Produkthaftung–Wohltat oder Plage: Eine ökonomische Analyse*, 30 BETRIEBS-BERATER 1, 5 (1987); *see* Francesco Silva & Alberto Cavaliere, *The Economic Impact of Product Liability: Lessons from the US and the EU Experience*, *in* REGULATORY REFORM AND COMPETITIVENESS IN EUROPE: HORIZONTAL ISSUES 292, 295 (Giampaolo Galli ed., 2000).

102. For simple examples, see STEVEN SHAVELL, ECONOMIC ANALYSIS OF ACCIDENT LAW 78-80 (1987);

In this situation where the consumer is fully informed of the accident risk, the optimal care and optimal production (activity) level will automatically be followed, irrespective of the legal rule. This result holds, both under strict liability, as well as under negligence, even in a no-liability setting. Indeed, the fully informed consumer will, as is demonstrated, only purchase the product taking into account its full price. In a no-liability setting, the consumer will add the expected loss to the (low) market price and still demand the product with the lowest full price. Applying the Coase theorem to the product liability case entails that an efficient result follows, no matter which legal regime applies. But this result depends upon the heavy assumption of full information of the consumer.

One has to understand that on paper this works perfectly, but the theories applying the Coase theorem to product liability rely on a very heavy assumption: full information of the risk caused by the GMO products. It is particularly this assumption of full information that has been subject to serious criticism. This can also be understood, particularly in the case of GMOs. However, one should make a distinction between the type of consumer that purchases the GMO related products. A distinction between commercial and non-commercial purchases may be indicated in this respect. Commercial purchasers, aware that they purchase GMOs products, may be well aware of the risk. In that respect, applying the Coase theorem is therefore not that strange. The story however changes in the case of ordinary consumers who have no information whatsoever with respect to the risk related to the GMO use. Generally it has been held that one solution to the lack of consumer information is to provide additional information on the risks through legislative measures. If these were successful the conditions for the Coase theorem could again be met. However, sometimes information may not help in providing better insights to the consumer. Recently, behavioral law and economics has also pointed at the fact that consumers' choices are often subject to a variety of so-called heuristics and biases. As a result, the ability of consumers to adapt their behavior (even if information is provided) may be limited.[103] These biases may also play a role in case of decisions made by consumers concerning the purchase of particular products. Hence, the possibility of curing heuristics and biases by providing additional information may be limited.

Then the question arises how liability law should react to this underestimation of the risk by consumers. It is generally held that if the consumer remains uninformed, non-liability will certainly not lead to an efficient result. The reason is that producers will in that case not have efficient incentives to invest in prevention of damage caused by GMOs. This is particularly the case if the benefit

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POLINSKY, *supra* note 73, at 96-97; *see also* Silva & Cavaliere, *supra* note 101, at 295.

103. *See generally* Christine Jolls, Cass R. Sunstein & Richard Thaler, *A Behavioral Approach to Law and Economics*, 50 STAN. L. REV. 1471 (1998) (for an excellent summary of behavioural law and economics); *see also* Russell B. Korobkin & Thomas S. Ulen, *Law and Behavioral Science: Removing the Rationality Assumption from Law and Economics*, 88 CALIF. L. REV. 1051, 1055 (2000).

of the investment (reduction of expected accident cost) is not recognized by the consumer.[104]

2. A Case for Strict Liability

It is generally held that in such cases fault-rule can induce the producer to take efficient care, but only a strict liability rule will lead to an optimal output of products. In this respect strict liability is considered to be a good remedy for underestimation of the risk by consumers.[105]

The latter conclusion is also true when harm is caused to third parties, *e.g.*, bystanders, who have no connection at all with the producer. A Coasean solution is of course excluded under these circumstances since the transaction costs will be prohibitive. There is also no "contact" between a producer and third parties through the price mechanism.[106] Again, a fault rule would induce the producer to take efficient care, but consumers would purchase too many products. Therefore, the market price would be too low, since it would not reflect the expected accident costs and, given this demand, an excessive output of products will follow.[107] This inefficiency can, again, only be remedied by the introduction of a strict liability rule. Since, under such a rule the market price will reflect the expected accident costs, both efficient care will be taken by the producer and an efficient quantity will be produced.[108]

Up to this point we have shown that the economic theory does not jump to hasty general conclusions with respect to the desirability of a fault or a strict liability rule. Such an answer depends on whether the victim is a consumer or a third party and if it is a consumer a further distinction is made depending on whether or not the consumer underestimates the risk of a product-accident. However, if consumers do underestimate the risk, or if the harm is caused to third parties, the literature clearly points to the advantages of strict liability from an efficiency viewpoint. These are mostly referred to as the full *internalization* of the harm through the strict liability rule. However, the economic theory does not stop here. We have assumed—until now—that the behavior of the victim had no influence on the accident risk, that both producers and consumers were risk-neutral and that the market was perfectly competitive. Other publications have

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104. This is especially stressed by Goldberg in a critique on the work by Oi. *See* Victor P. Goldberg, *The Economics of Product Safety and Imperfect Information*, 5 BELL J. ECON. & MGMT. SCI. 683, 683 (1974). For a reaction see Walter Y. Oi, *The Economics of Product Safety: a Rejoinder*, 5 BELL J. ECON. & MGMT. SCI. 689 (1974).

105. *See* Adams, *supra* note 101, at 12; POLINSKY, *supra* note 73, at 99; Shavell, *supra* note 75, at 14-17 (providing formal proof of the proposition); *see also* Silva & Cavaliere, *supra* note 101, at 295.

106. *See* Koichi Hamada, *Liability Rules and Income Distribution in Product Liability*, 66 AM. ECON. REV. 228, 230 (1976); Cento G. Veljanovski, *The Economic Theory of Tort Liability—Toward a Corrective Justice Approach*, *in* THE ECONOMIC APPROACH TO LAW 125, 130-31 (Paul Burrows & Cento G. Veljanovski eds., 1981).

107. *See* POLINSKY, *supra* note 73, at 103; Shavell, *supra* note 102, at 49-50.

108. Shavell, *supra* note 75, at 3.

shown that when these assumptions are relaxed, the advantage of strict liability, as expressed earlier, does not prevail.

It has been stressed that in a bilateral accident situation where the victim also influences the accident risk, liability rules should also give the victims an incentive to take appropriate care and not to engage too often in dangerous activities. If the victim has an important influence on the accident risk most authors hold that a fault rule will be preferred to a strict liability rule, even if the latter is combined with a contributory negligence defense. One of the reasons given is the unwillingness of courts to consider the contributory negligence of victims, which might easily affect their incentives. In addition, only a fault rule will lead to an efficient activity level by the victim. It is therefore held that if the victim has an important influence on the accident risk and it is thus more important to control his activity level than it is to control the injurer's, a fault rule will be preferred.[109]

In sum, the economic theory advances strong arguments in favor of a strict liability rule when consumers underestimate the risk of a product accident or when the harm is caused to third parties. However, if the victim has a substantial influence on the accident risk, or if the producer has market power and the consumers underestimate the accident risk, or if one takes into account the influence of insurance, strong arguments could be advanced in favor of a fault rule. Again, just as we stressed as far as the general choice between strict liability and negligence is concerned, it all depends on whether one considers the GMO risk as a unilateral or bilateral accident case. That choice may well depend on the type of victim; in the case of commercial users, accidents may have a bilateral nature since the victim should also be given incentives to reduce the accident risk. However, if the victim is a consumer without specialized information, the measures the victim could take to reduce the risk may be very limited. That would make the accident a unilateral type accident where strict liability may be preferable.

Notwithstanding these theoretical observations on the nature of product liability, product liability may in legal practice only come into play if indeed consumers would suffer harm as a result of a genetically modified product. However, as we showed above, most of the liability cases with respect to GMOs so far were brought by organic farmers suffering harm as a result of GMOs used by their neighbors. At first blush it could be argued that this is not a product liability case because the relationship between a producer (of GMOs) and the damage (to the third party, organic farmers) is too remote, and because it is not the final product that causes the harm to the neighbor, rather a production method. Still, the *StarLink* litigation, discussed above, showed that third parties were

109. *Id.* at 7, 20; Shavell, *supra* note 102, at 48-51 (this will often be dependent upon the nature of the activity and the potential harm).

allowed to bring a claim under the Tennessee Consumer Protection Act.[110] Hence, the applicability of product liability rules in this case cannot completely be ruled out either.

E. INFLUENCE OF REGULATION

So far, we have presented liability rules from an economic perspective as instruments to providing incentives to prevent damage caused by GMOs. In reality, of course, GMOs are subject to a great deal of safety regulation. The goal of this safety regulation is precisely the prevention of damage. Thus, a much more important role will be played, in practice, by safety regulation than by liability rules, at least as far as prevention is concerned. This, by the way, also corresponds with the economic criteria for safety regulation as they have *inter alia* been developed by Shavell.[111] Indeed, information on the optimal ways to prevent damage caused by the use of GMOs is probably more readily available to a regulator than with the potentially liable operator. Thus, the informational advantage is the *first* important criterion in favor of safety regulation. *Second*, there may be a serious insolvency risk. The insolvency risk arises from the moment that the damage that could result from the use of the GMO would be higher than the assets of the person liable for that particular use. The damage can be catastrophically high, especially if one imagines damage along the food chain with far-reaching consequences to many consumers, or at least leading to large economic losses. There is always the likelihood that operators are organized as legal entities. Legal entities generally enjoy limitation of liability and thus there is always the danger that they will externalize harm to third parties.[112] *Third*, there may be a risk that there is a long time lapse between the moment that the source of GMO damage takes place and the moment that the damage occurs. In addition, there may be difficulties for the victim to prove a causal relationship between his damage and the acts of a particular operator. These latency and causation problems may lead to situations whereby tort law is not used, even though the conditions for liability are fulfilled. Thus, when the threat of a liability suit will not provide a sufficient deterrent effect, this provides another argument in favor of regulation.

Although Shavell's criteria thus provide a strong argument to control GMO risks ex ante through regulation, in individual cases there can still be damage. Then again, liability under tort comes into the picture and the question of course

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110. *In re* StarLink Corn Prod. Liab. Litig., 212 F. Supp. 2d 828, 851-52 (N.D. Ill. 2002).

111. *See* Steven Shavell, *Liability for Harm Versus Regulation of Safety*, 13 J. LEGAL STUD. 357, 369-370 (1984).

112. *See* Henry Hansmann & Reinier Kraakman, *Towards Unlimited Shareholder Liability for Corporate Torts*, 100 YALE L.J. 1879, 1879-81 (1991). Because of this danger of using the corporate structure for externalizing harm to involuntary creditors, Hansmann & Kraakman argued in favor of unlimited shareholder liability for corporate torts.

arises of how regulation influences the liability system and vice versa.

The first question that arises is whether violation of a regulatory standard concerning GMOs should automatically be considered a fault under tort law and thus lead to liability. Most legal systems consider a breach of a regulatory duty evidence of negligence per se.[113] One of the reasons for introducing safety regulations to control GMO risks is, as mentioned above, that the regulator will usually possess better information to evaluate the efficient standard of care than the parties involved. Hence, regulation passes on information to the parties on the efficient standard of care, but does so equally to the judge. The judge may lack the necessary information to find out what the particular standard is that could be required from the person handling the GMO. Therefore, the statutory standard can guide the judge in a liability case.

A more difficult question may arise as to whether compliance with a regulatory standard could release an injurer from liability. Bergkamp, for example, argues that where risk assessment and monitoring have found no significant risk could arise from the release of GMOs and so long as the release is conducted in accordance with regulations and conditions, no liability for unknown risks is likely to be imposed.[114] In this case, an injurer may argue that the damage is in fact unforeseeable.[115] However, as Smyth and others have put it, although regulatory standards have been followed, many species could still roam and cross-pollinate to their wild relatives, which potentially would create environmental problems.[116] This means that a regulatory standard does not necessarily remove the risks of damage, since some species may roam beyond the buffer zone and pollinate with other plants and potentially cause damage as well. The question will be whether the impacts of such pollination are significant. In this case, the injurer may still be found liable although he has complied with the regulatory standards.[117]

Consequently, although the noncompliance with a regulatory standard is a sufficient reason for injurer's liability, the reverse is not true; regulation should

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113. *E.g.*, Kenneth S. Abraham, *The Relation Between Civil Liability and Environmental Regulation: An Analytical Overview*, 41 WASHBURN L.J. 379, 384 (2002).

114. Bergkamp, *supra* note 45, at 21.

115. In this regard, Rodgers argues that when risk assessment prior to a commercial release of GMOs found only negligible risk, it will be difficult for the defendants to establish that the resulting damage was indeed foreseeable before the release. Christopher P. Rodgers, *Liability for the Release of GMOs into the Environment: Exploring the Boundaries of Nuisance*, 62 CAMBRIDGE L.J. 371, 390, 400 (2003).

116. Smyth et al., *supra* note 48, at 537-38. As quoted by Endres, a study conducted in the U.K. found pollen from GM crops had been carried by bees 4.5 kilometres away from the test field. *See* Endres, *supra* note 84, at 456.

117. Khoury & Smyth argue that although a risk assessment prior to an authorization of GM crops revealed the remoteness of risks, these risks could still be considered foreseeable based on public concerns. This is because, as the authors argue, the absence of knowledge does not mean the absence of public concern about possible risks. As a result, the injurer will still be held liable if these risks materialize in the future. To support this argument, the author resorts to the precautionary principle, by which the injurer is liable when the uncertain risks of serious magnitude materialize in the future. Khoury & Smyth, *supra* note 48, at 226-28.

not, from an economic perspective, necessarily free the GMO operator from liability. The reason to reject this so-called regulatory compliance defense from an economic perspective is that the regulatory standard is in some cases merely a minimum.[118] The efficient standard can be higher and thus liability should supplement regulation in this case to provide the GMO operator incentives to take efficient care to prevent the damage.[119] Exposure to liability does provide the GMO operator with incentives to take all efficient precautions, even if this requires more than merely following the regulation. Moreover, liability is an important remedy for the unavoidable capturing of administrative agencies, which may lead to inefficiently low regulatory standards. Exposing the GMO operator to liability even though the operator followed regulations or the conditions of a license is thus, from an economic perspective, an important tool to guarantee that the operator will take efficient care.

In addition, the discussion of the regulatory standard should also include how the release of GMOs would be overseen. In such a case, it is not unusual that the oversight of the release is left to the seed company.[120] Clapp argues that the tendency to apply lenient compliance monitoring, in which the compliance with regulatory standards depends largely on the self-reporting and self-monitoring conducted by the seed companies, has contributed to some cases of illegal release of GMOs in the United States.[121] This point confirms that following a lenient

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118. Some countries may not have only minimum, but also sub-optimal regulatory standards for GMOs. *See, e.g.*, the critics of Bratspies concerning the US regulation on the commercialization of Bt crops. She argues that the agencies responsible for the release of Bt crops have abandoned the precautionary principle, and instead used the most optimistic estimates as the basis of their decision. In addition, there is no clear mechanism to ensure the growers' compliance with the requirement set by the seed companies, as it could be assumed that it is not in the companies' interest to enforce their requirement. *See* Rebecca Bratspies, *The Illusion of Care: Regulation, Uncertainty, and Genetically Modified Food Crops*, 10 N.Y.U. ENVTL. L.J. 297, 346 (2002). Assuming that this allegation is true, releasing an injurer just because he has followed such a non-optimal regulatory standard, may create too many harms for society, in which case the price of GM products would not represent the true social costs.

119. *Cf.* Paul Burrows, *Combining Regulation and Legal Liability for the Control of External Costs*, 19 INT'L REV. L. & ECON. 227, 237 (1999).

120. The commercial release of GMOs by individual farmers is usually based on contractual agreements, by which the seed company specifies certain procedures in planting its GM seed. For example, the company usually requires the GM growers to meet the permissible use of the GM seed and prohibits the seed saving or seed transfer to third parties. Based on these agreements, the company will then monitor the farmers' compliance with the agreements. *See*, de Beer, *supra* note 58, at 293.

121. Clapp found that in three cases of illegal release of GMOs, i.e. the *StarLink* case (GM corn for animal feed is found in food supply), the Bt10 maize case (unapproved GM maize was found in the seed and food supplies), and the Liberty Link RICE 601 case (unapproved GM rice was found in rice supplies), the seed companies failed to detect the illegal release and inform the authority about the release, since in all three cases the illegal release was initially detected by other parties. In addition, Clapp also found that rather than improving their monitoring systems, the companies either blamed the farmers for the illegal release or asked the regulatory agency to issue a retroactive approval for the previously unapproved seeds. Accordingly, Clapp concludes that heavy reliance on voluntary corporate measures, such as self-monitoring and self-reporting, has failed to induce compliance with the regulatory standards. Jennifer Clapp, *Illegal GMO Releases and Corporate Responsibility: Questioning the Effectiveness of Voluntary Measures*, 66 ECOLOGICAL ECON. 348, 352-355

regulatory standard should not be a defense, since such a standard will certainly fail to induce potential injurers to take the optimal preventive measures.

IV. CAUSATION

A. GENERAL

Problems can of course arise as far as the requirement that a causal link be established between the alleged damage and the presence of the particular GMO concerned. The economic analysis of law has paid considerable attention to the requirements that should in general be attached to causation. It would lead us too far afield to discuss these in any detail at this moment.[122] Shavell explains in clear words that there is a good economic reason to limit the liability of an injurer to the cases he has really caused.[123] If the requirement of a causal link would not have this limiting effect on liability, the result would be that many potentially beneficial activities in society would no longer take place because in effect an operator would then also be held liable for damage that would not result from his acts.[124] A liability for damage that is not the result of the activity of the operator would thus be considered as crushing, as Shavell holds.[125] Thus, it makes good sense to limit the liability of the operator who handled GMOs to the damage actually caused by the GM crop.[126]

B. BURDEN OF PROOF

Where there is uncertainty over causation, an early question that arises is on whom the burden of proof should rest in a case. Uncertainty can arise, for instance, when there may be many different sources and it is not clear what precisely caused the damage to a non-GM crop. Also, there may be multiple causes. Regarding all of these issues of causal uncertainty, there is both a procedural aspect (who should bear the burden of proof?) and a contents aspect (how should the law deal with uncertainty over causation?).

Traditionally, the plaintiff, i.e., the victim, should bear the burden of proof regarding the elements of the liability rule that he uses to claim damages.[127] He

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(2008).

122. *See generally* Guido Calabresi, *Concerning Cause and the Law of Torts: An Essay for Harry Kalven, Jr.*, 43 U. CHI. L. REV. 69 (1975); Steven Shavell, *An Analysis of Causation and the Scope of Liability in the Law of Torts*, 9 J. LEGAL STUD. 463 (1980); Landes & Posner, *supra* note 73, at 851.

123. Steven Shavell, *Uncertainty over Causation and the Determination of Civil Liability*, 28 J.L. & ECON. 587, 588 (1985).

124. *Id.*

125. *See* Shavell, *supra* note 102, at 108.

126. *See generally* Omri Ben-Shahar, *Causation and Foreseeability*, *in* TORT LAW AND ECONOMICS 83 (Michael Faure ed., 2009).

127. In the absence of a specific liability system for GMOs, the victim should resort to one of several liability rules, namely trespass, private nuisance, negligence, strict liability, or product liability. Each of these rules has

should, for example, prove that he has suffered damage and that this damage was the result of exposure to a GM crop. Almost inevitably, the victim will need to rely on expert opinion to support his claim.[128]

However, one may argue that the court may place the burden of proof on those who can acquire information more cheaply. In this regard, shifting the burden of proof to the GM operators could be justified for several reasons. First, the shifting of the burden of proof may release the victims from the difficult task of proving their claims. Second, it could also be argued that GM operators have control over GMOs, and thus they are in a better position to control any resulting damage from GMOs, and to acquire information regarding the impacts of GMOs. Third, as Clapp has argued, in cases when uncertainty is prevalent, such as in the development and release of GMOs, there is information asymmetry in favor of GMO operators.[129] In this case, the reversal of the burden of proof may function as a counter against information asymmetry.[130]

Based on such an efficiency argument, the more important question will no longer be about the burden of proof, but about the standard of proof. The issue of standard of proof is particularly important if we are faced with uncertainty concerning causality.

C. CAUSAL UNCERTAINTY

There is a real likelihood that, as we just mentioned above, many issues of causal uncertainty could arise in cases in which non-GM crops cause damage to third parties. Uncertainty could, for example, arise concerning the question of whether GM crops have caused the damage. In that case, the causal uncertainty relates to the source of the damage. In other (or the same) cases, there could be uncertainty concerning the question of which of various GM crops may have caused the loss. There can indeed be different sources of the presence of GMOs. Then the question arises of how the law should deal with uncertainty when it cannot be established with certainty who caused the problem. This is especially

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its own elements that should be proven by the victim. For a brief summary of the elements of nuisance, negligence, and strict liability, see Tana N. Vollendorf, *Genetically Modified Organisms: Someone is in the Kitchen with DNA Who is Responsible When Someone Gets Burned?*, 21 MISS. C. L. REV. 43, 48-53 (2001).

128. The burden of proof borne by the victim might be reduced if GM products were required to be labeled with their genetic markers, as has been proposed in Europe. *See* Endres, *supra* note 84, at 487.

129. Clapp, *supra* note 121, at 355-56.

130. Gollier argues that self-interested firms may exploit the favorable asymmetry information for their own benefits by, for example, introducing their inventions as soon as possible in order to preempt the market of these products. Christian Gollier, *Should We Beware of the Precautionary Principle?*, 16 ECON. POL'Y 303, 313-314 (2001); *see also* Christian Gollier & Nicolas Treich, *Decision-Making Under Scientific Uncertainty: The Economics of the Precautionary Principle*, 27 J. RISK & UNCERTAINTY 77, 98 (2003) (arguing that under the situation of uncertainty, competitive firms may introduce their products before fully assessing the possible impacts of the products). With respect to GMOs, this situation might be indicated by poor pre-market testing of GMOs or inefficient voluntary control of the release, as illustrated in three cases studied by Clapp. Clapp, *supra* note 121.

true if liability is channeled to the farmers, by which the plaintiff has to prove which of the neighboring GM farmers has caused the damage. The situation will be less difficult for the plaintiff if liability is channeled to the seed company, since the trait of the GM crop is identifiable and usually corresponds to the damage in question.[131]

Potentially, the law could provide a variety of solutions to the causal uncertainty problem. One could, on the one hand, judge that as soon as there is any statistical chance that a certain activity (or product) may cause certain damage, all victims receive 100% compensation of their damage.

The second possibility is to refuse the claim of the victim unless there is 100% certainty that the tort caused the damage.

The third possibility is to award compensation only when the probability that the damage was caused by the tort passes a certain threshold of, say, 50%. This threshold rule is a kind of "all or nothing" approach. If the probability is lower than the threshold, the victim receives no compensation at all; if the probability is higher than the threshold, the victim receives full compensation. This threshold rule is known in American literature as the "more probable than not" solution, referring to the fact that the plaintiff must convince the judge that the damage suffered was "more probably than not" caused by the tort.[132]

The final solution is to take into account the probability that the tort caused certain damage and to award compensation, considering this probability. This would mean that if the scientific expertise indicates that the likelihood of damage is, say, 40%, then the victim can receive compensation for 40% of his damage.

The way the law should deal with causal uncertainty has been addressed extensively in the economic literature, for instance, by Rosenberg,[133] Kaye,[134] and Shavell.[135]

Let us address more closely the various options addressed above. The *first* option would be to award a victim total compensation of damage, even if the probability that his loss was actually caused by the injurer's activity was relatively low, say 30%. In such a case, this means that we also know that there is a 70% probability that the damage (e.g., a certain illness) was caused through another event. If an injurer is held liable for the full amount even if there is only a

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131. To illustrate this situation, one could refer to the *StarLink* case, in which StarLink corn developed for animal feed was found in the food supply. In this case, it was not difficult to determine who the responsible company was, since this patented GM corn was produced by Aventis. However, it was not possible to determine which particular farmers had caused the co-mingling between the GM feed corn and non-GM food corn. For detailed information on this case, see Bratspies, *supra* note 118, at 352-53.

132. *See* Richard A. Epstein, *A Theory of Strict Liability*, 2 J. Legal Stud. 151 (1973).

133. *See generally* David Rosenberg, *The Causal Connection in Mass Exposure Cases: A "Public Law" Vision of the Tort System*, 97 HARV. L. REV. 849 (1984).

134. *See* David Kaye, *The Limits of the Preponderance of the Evidence Standard: Justifiably Naked Statistical Evidence and Multiple Causation*, 7 AM. B. FOUND. RES. J. 487, 503-16 (1982).

135. *See* Shavell, *supra* note 123.

30% probability that his activity caused a loss, this will lead to too few incentives to invest in a socially desirable activity, such as the development of genetically modified organisms.

This shows that the first solution, simply arguing that in the case of causal uncertainty the victims can claim full compensation, is inefficient and unjust. The same is true for the second solution in which it would be required that the victim prove with 100% certainty that his damage has been caused by the tort. That requirement would mean that in many cases injurers would escape the clutches of the law, whereas their activities have effectively created an additional risk. Therefore, that solution would amount to underdeterrence.

This, therefore, leaves us the two other solutions often seen in tort law: either the requirement that a certain threshold should be passed or proportionate liability.

Threshold liability leads to a situation whereby the victim's claim is totally accepted if the probability passes the threshold of, say, 50%. If the probability passes the threshold, compensation is in full, but if the probability is lower than the threshold, the victim receives no compensation at all. The disadvantages of this hard and fast solution are obvious. One problem, both from the victim compensation perspective as well as from the deterrence perspective, is that the probability of causation could systematically be lower than the threshold. Assume that the probability were systematically 40% that a certain cancer was caused as a result of a certain activity. If the threshold was 50% this would mean that the enterprise exposing persons to this 40% risk would systematically escape the clutches of the law. Victims would not be compensated and the incentives toward accident reduction would be too low.[136] This seems inefficient and probably also unjust, since the enterprise has created certain losses in a number of cases, at least statistically. Assume that 100 victims all file a lawsuit; in this particular example, one would assume that 40 out of these 100 cases would have been caused by the emissions emanating from the particular enterprise. However, for every individual the probability of causation would always be below the 50% threshold, so that the enterprise would not be held to compensate the victims in any of these cases. That is a clear disadvantage of this "all or nothing" approach, which is inherent in threshold liability.

A more fine-tuned alternative can be found by translating the probability of causation by awarding the victim a proportionate amount of his damage. In practice, this would mean that if the probability that the victim's damage was caused by the injurer's activity was 40%, the victim would be compensated for 40% of his damage. From an economic perspective, the advantage of this proportionate liability is that it exposes the injurer precisely to the excess risk (in this case the additional number of cancer cases) that was caused by the (assumed

136. *Id.* at 588.

wrongful) activity of the injurer. The enterprise will then, returning to the previous example, have to compensate 40% of all the damage of every particular victim, which amounts at the aggregate level to the same as compensating 40 out of 100 victims whose illness would have been caused by the enterprise.[137]

The result of this proportionate liability is that the injurer receives optimal incentives for prevention, since he is precisely exposed to liability for the risk that was caused by his activity.[138] Economic literature holds that a proportionate liability rule therefore provides optimal incentives for accident reduction[139]

This proportional liability rule limits the negative consequences of causal uncertainty. A proportionate liability rule is less rigorous than the all-or-nothing approach entailed by the reversal of the burden of proof.[140] The proportionate liability rule would indeed mean that all victims can claim a proportion of their damage equal to the amount by which the power plant contributed to the loss. Thus, the exposure to liability of the enterprise corresponds precisely with the amount to which the power plant contributed to the risk.[141] This proportionate liability rule could, more particularly in cases of product liability, take the form of market share liability.[142]

V. MULTIPLE TORTFEASORS

A related problem, also having to do with causal uncertainty, is how one should handle the situation where multiple actors are involved. This can again have different sources. It could also be the case that there are potentially many GM crops that have affected the non-GM crops (if the damage would consist of cross pollination). The other possibility is that there are various liable actors in the vertical production chain. But similar questions also arise when damage is caused to third parties. Again, as with the general issue of causal uncertainty, the law has basically a variety of options to solve this issue. The most realistic ones (and thus applied in the legal system) are on the one hand joint and several liability and on the other hand proportional liability. So-called market share liability, whereby the

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137. *Id.* at 589.

138. LUCAS BERGKAMP, LIABILITY AND ENVIRONMENT: PRIVATE AND PUBLIC LAW ASPECTS OF CIVIL LIABILITY FOR ENVIRONMENTAL HARM IN AN INTERNATIONAL CONTEXT 290-291 (2001).

139. *See* John Makdisi, *Proportional Liability: A Comprehensive Rule to Apportion Tort Damages Based on Probability*, 67 N.C. L. REV. 1063, 1070-1073 (1989); William M. Landes & Richard A. Posner, *Tort Law as a Regulatory Regime for Catastrophic Personal Injuries*, 13 J. LEGAL STUD. 417, 425-431 (1984); Glen O. Robinson, *Probabilistic Causation and Compensation for Tortious Risk*, 14 J. LEGAL STUD. 779, 784 (1985). For a discussion of the possible legal foundation of a proportionate liability rule, see Michael Faure & Véronique Bruggeman, *Causal Uncertainty and Proportional Liability*, *in* CAUSATION IN LAW, 105-21 (Tichy ed., 2007).

140. *See* Gert Brüggemeier, *Liability for Water Pollution under German Law: Fault or Strict Liability*, *in* TRANSBOUNDARY POLLUTION AND LIABILITY: THE CASE OF THE RIVER RHINE 83, 88-91 (Jan M. van Dunné ed., 1991).

141. Robinson, *supra* note 139, at 798.

142. *See* Pierre Widmer, *Causation under Swiss Law*, *in* UNIFICATION OF TORT LAW: CAUSATION 105, 112-13 (Jaap Spier ed., 2000).

liability is apportioned according to the market share of the operator, is an example of such a proportionate solution to multi-actor causation.[143] In addition to joint and several liability and the proportional liability, the law might also solve the problem of multiple tortfeasors by statutorily channeling liability to a specific party, e.g. the manufacturer of GMOs.

A. JOINT AND SEVERAL LIABILITY AND PROPORTIONAL LIABILITY

At first sight, a joint and several liability rule appears to be a regime whereby the legal system deviates from the principle that a tortfeasor should only be held liable for the damage that was caused by his own behavior. Under joint and several liability, the tortfeasor is held liable in full also for damage that was not caused by his own behavior.

Therefore, at first blush, one could argue that a joint and several liability system seems inefficient, since it leads to overdeterrence. The injurer's liability is not limited to the risk created by his own activity. However, such a simple conclusion is (as usual) indeed too simple. One may argue that a distinction should be made between the situation of full solvency of all the contributing tortfeasors on the one hand and the situation in which either one or more of them is insolvent. In case of full solvency of all the actors, one can argue that there is no efficiency loss caused by joint and several liability.[144] In that case, the injurer who has to compensate the victim can in turn exercise a redress against the other parties who contributed to the loss in proportion to their contribution. Assuming that the other tortfeasors are fully solvent, the one who paid first only pre-finances the compensation of the victim and will be able to recover a part of the damages paid. Thus, in the end, also under joint and several liability, the extent to which every contributor has to pay should be proportionate to his contribution to the risk. In that sense, a joint and several liability rule, combined with a right of recourse and solvent actors, amounts to a proportionate solution. The exposure to liability of every tortfeasor in this model is limited to his own contribution to the loss and thus optimal incentives would follow.

Of course one could wonder what the additional benefit is of a joint and several liability rule compared to the situation wherein the victim would have to sue every individual tortfeasor separately. One could make a victim protection argument, simply on the basis of the fact that for the victim it is often more difficult to prove a causal link with the action of one particular actor. Thus, it certainly simplifies procedural matters for the victim if the victim can claim full

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143. For a recent overview of the economic literature, see Lewis A. Kornhauser & Richard L. Revesz, *Joint and Several Liability*, *in* TORT LAW AND ECONOMICS 109 (Michael Faure ed., 2009).

144. For a detailed analysis of joint and several liability when all defendants are fully solvent, see generally Lewis A. Kornhauser & Richard L. Revesz, *Sharing Damages Among Multiple Tortfeasors*, 98 YALE L.J. 831 (1989). For the analysis in case of limited solvency, see generally Lewis A. Kornhauser & Richard L. Revesz, *Apportioning Damages Among Potentially Insolvent Actors*, 19 J. LEGAL STUD. 617 (1990).

compensation from one injurer, who then has to exercise the right of redress against the other parties who contributed to the loss. However, in addition to this distributional argument, there are undoubtedly efficiency arguments in this particular case as well. They are probably not linked to a benefit in administrative costs. Indeed, whether either the victim has to sue, for example, five different tortfeasors or the victim just sues one tortfeasor and the latter exercises a right of redress probably does not create much difference as far as the administrative costs are concerned. However, one could make the argument that joint and several liability may give *ex ante* excellent incentives for mutual monitoring among potential joint tortfeasors.[145] Indeed, victims may well encounter difficulties in proving a causal link between the action of every particular tortfeasor and the loss he suffered. That may result in too few claims and hence in underdeterrence. Shifting the risk to the injurers would mean that they *ex ante* have an excellent incentive to mutually monitor their activities. Joint and several liability in fact shifts the risks of uncertainty concerning the proof of the causal link to the injurers. The victim can succeed by suing just one of the many potentially liable injurers and claiming full compensation. If the one injurer who is sued does not succeed in proving that others contributed to the loss, the damage will ultimately fall on him.

However, these arguments may not be valid if the tortfeasors are insolvent.[146] In that case, the risk of insolvency is shifted to the injurer who will be sued by the victim. In that particular case, one would assume that, e.g., only the solvent injurer is sued by the victim and he has no right of recourse (given the insolvency of the others). The effect would be that one (solvent) injurer would be held to compensate for losses that he has not caused.[147] In case of insolvency, joint and several liability may thus violate the principle that the injurer should only be held liable to compensate in proportion to the loss.

B. THE CHANNELING OF LIABILITY

One possible solution when various actors are potentially involved is to impose liability exclusively on one of those parties and to exclude the liability of all others. For example, this solution has been followed in the nuclear liability conventions, whereby the liability is channeled to the licensee of a nuclear power

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145. An argument in that direction is made by Tom Tietenberg, *Introduction and Overview*, *in* INNOVATION IN ENVIRONMENTAL POLICY: ECONOMIC AND LEGAL ASPECTS OF RECENT DEVELOPMENTS IN ENVIRONMENTAL ENFORCEMENT AND LIABILITY 1, 5 (T.H. Tietenberg et al. eds.,1992).

146. Boyd & Ingberman argue that under certain conditions extended liability may promote cost internalization, but that there are serious drawbacks as well. Hence, they argue that other solutions should be examined to cure the problem of undercapitalization. James Boyd & Daniel Ingberman, *The Vertical Extension of Environmental Liability Through Chains of Ownership, Contact and Supply*, *in* THE LAW AND ECONOMICS OF THE ENVIRONMENT 44 (Anthony Heyes ed., 2001).

147. Then joint and several liability would lead to overdeterrence, so Bergkamp rightly argues. BERGKAMP, *supra* note 138, at 301.

plant.[148] A channeling of liability to the tanker owner can be found in the conventions concerning damage caused by marine oil pollution; usually this channeling of liability means that one party is exclusively liable, which means that victims cannot bring a suit against other parties who might have contributed to the damage as well.[149] In the case of GMO liability, the channeling of liability means that the producer of GMOs will be exclusively held liable for the damage caused by its product. However, it appears that only a few countries have indeed statutorily channeled liability to the manufacturer of GMOs.[150]

Channeling of liability is sometimes defended as a device that would make the life of the victim easier.[151] The victim would then know *ex ante* exactly against whom a law suit would have to be brought and difficult procedural issues in the case of multi-actor causation could be avoided. Also, it is sometimes argued that channeling would increase the insurability of particular risks, since only one party would have to take insurance cover.[152] Nevertheless, the overall appreciation of channeling of liability from an economic perspective is rather negative. Indeed, it has been argued that this channeling is inefficient because it has perverse effects on the incentives for care where the liability applies exclusively to one operator.[153] This is the case if channeling means that victims no longer have the right to sue another party who could influence the accident risk as well. Excluding that third party from liability is inefficient, because his incentives for prevention are diluted. That effect is obviously reduced if the licensee or operator who would be held liable still has a right of recourse against the third party or if a liability could be passed on the basis of contract, for example. In that case one could argue that the liability is simply transferred and that such a reallocation complies with the principles of the Coase theorem.[154]

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148. Michael G. Faure and Tom Vanden Borre, *Compensating Nuclear Damage: A Comparative Economic Analysis of the US and International Liability Schemes*, 33 WM. & MARY ENVTL. LAW & POL'Y REV. 219 (2008).

149. Tom Van den Borre, *Channelling of Liability: A few Juridical and Economic Views on an Inadequate Legal Construction*, *in* Nathalie L.J.D. Horbach (ed.), *Contemporary Developments in Nuclear Energy Law: Harmonizing Legislation in CEEC/NIS* 13 (Nathalie Horbach ed., 1991).

150. For a discussion on the channeling of liability in several countries, see, e.g., MICHAEL MIGUS, GMO STATUTORY LIABILITY REGIMES: AN INTERNATIONAL REVIEW, 17-19 (Canadian Institute for Environmental Law and Policy 2004), *available at* http://www.cielap.org/pdf/GMOLiability.pdf. The Intergovernmental Committee for the Cartagena Protocol on Bio-safety has also compiled several reports from several countries concerning the application of liability and redress related to damage resulting from GMOs. *See generally* Intergovernmental Committee for the Cartegena Protocol on Biosafety, *Compilation of Information on National, Regional, and International Measures and Agreements in the Field of Liability and Redress for Damage Resulting from the Transboundary Movements of Living Modified Organism*, U.N. Doc. UNEP/CBD/ICCP/3/INF/1 (April 2, 2002).

151. Norbert Pelzer, *International Pooling of Operators' Funds: An Option to Increase the Amount of Financial Security to Cover Nuclear Liability?*, 79 NUCLEAR L. BULL. 37, 46 (2007).

152. *Id.*

153. For a critical economic analysis of the channeling of nuclear liability, see Van den Borre, *supra* note 149.

154. *See* Michael Trebilcock & Ralph A. Winter, *The Economics of Nuclear Accident Law*, 17 INT'L REV. L. & ECON. 215, 232-35 (1997).

However, this private reallocation of liability may not always be possible, and some of the conventions, moreover, even restrict the possibilities of a right of recourse. Therefore, channeling can hardly be considered an efficient mechanism for the prevention of accidents. In addition to this principal economic argument, one could also argue that at the practical level, channeling of liability might be difficult to introduce in the area of GMO damage. In case of oil pollution or nuclear accidents, it is relatively easy to identify one liable party to whom liability can be "channeled," such as an operator or tanker owner. However, in cases of damage caused to non-GM crops by GMO crops, it is far more difficult for the legislator to identify to whom a potential liability should be channeled *ex ante*. Hence, in addition to the principal arguments against channeling, one can equally wonder whether it would be practically possible to implement it.

Channeling of liability to the manufacturer may have great advantages for the victim, because there can be no doubt as to who is liable when damage is caused by a GMO. Some of the cases discussed above where the claims were based on either negligence, strict liability, trespass or nuisance equally showed that in the absence of a channeling of liability it may in practice be difficult to hold a manufacturer of GMOs liable. This is clearly indicated in *Hoffman v. Monsanto*, in which the dismissals of strict liability, nuisance, and trespass claims were, to some extent, related to the fact that the defendants were GMO manufacturers, and not GMO farmers. With respect to the application of strict liability to the case, Judge Smith argued:

> Regardless of whether one considers GM canola a "dangerous substance," or the field trials for GM canola an "unnatural" or "non-natural" use of land, it is not reasonably arguable that the commercial release and sale of Roundup Ready canola seed and Liberty Link canola seed constituted an "escape" of a substance, dangerous or otherwise, from property owned or controlled by the defendants in the sense of "escape" required by the rule in *Rylands v. Fletcher*. It is my conclusion that the pleadings do not disclose a reasonable cause of action based on the rule in *Rylands v. Fletcher*.[155]

In our opinion, the above argument implies that the strict liability claim is rejected because merely releasing and selling GM crops cannot be considered an escape of dangerous substances. Such an interpretation, where the marketing of GMOs creates the possibility of GM crops cross-pollinating with non-GM crops, or escaping the control of users once the crops are planted, does not necessarily lead to strict liability, because strict liability requires that the escape stem from property owned or controlled by the defendants.

The court also dismissed the nuisance claim on the grounds that liability cannot be applied to the manufacturer of a damaging substance when the damage that occurred was beyond the point of sale. In this regard, the court stated that:

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155. Hoffman v. Monsanto Canada Inc., 2005 SKQB 225, 264 Sask. R. 1, para. 97 (Can. Sask. Q.B.).

> The adventitious presence of canola in the crops and on the land of organic farmers required the intervention of neighbouring farmers who cultivated GM canola. Holding the defendants liable in nuisance on the basis of the commercial marketing of the product would be equivalent to holding the manufacturers of pesticide responsible for the nuisance caused by the harmful drift of the pesticide. While the "release" of the GM varieties of canola by the defendants may have been a necessary condition for the occurrence of the harm alleged, it was far from sufficient, in itself.[156]

In the ruling quoted above, the judge considered that the damage requires not only the sale of GMOs, but more importantly the planting of GMOs. As for a strict liability claim, the judge seemed to be of the opinion that manufacturers of GMOs cannot be held liable for the damage simply because they have produced and marketed the GM product.

Finally, concerning the trespass claim, the court rejected it because "it is clear that much more than 'natural and inevitable forces' must intervene between merely marketing GM canola and its arrival on the plaintiffs' land."[157] Furthermore, the court concluded that "action in trespass does not lie against the defendants as the inventors and marketers of GM canola for the adventitious presence of GM canola in the crops and on the lands of organic grain farmers."[158]

When liability rules are not applicable to the producers of GMOs, as was apparent in the *Hoffman v. Monsanto* case, one may expect that the plaintiffs have to stage claims against the GM farmers. This is a very unfortunate situation for the plaintiffs because finding particular GM farmers whose crops have created damage to the plaintiffs is presumably much more difficult than finding the producers of those damaging products.

The ruling of *Hoffman v. Monsanto* has nevertheless drawn many critiques, which mainly criticize the ruling as being based on a rather narrow interpretation of liability rules.[159] Indeed, some of the plaintiffs' claims were rejected not because the plaintiffs failed to show the evidence that they were injured by GM crops, i.e., GM canola, but because the liability rules were considered not applicable to the defendants as the producers of GM canola. In particular, some critiques argue against a narrow interpretation of the *Hoffman v. Monsanto* court with respect to the issue of "control." Contrary to the court's opinion, the critiques argue that the producers of GMOs could be held liable for the damage that occurs after the point of sale, because the producers of GM crops in principle still have the control over the GM crops through various agreements with the

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156. *Id.* at para. 114.

157. *Id.* at para. 131.

158. *Id.* at para. 133.

159. For a general critique against the ruling of *Hoffman v. Monsanto*, see generally Martin Z.P. Olszynski, Hoffman v. Monsanto Canada Inc.*: Looking for a Generous Approach to the Elephant in the Garden*, 16 J. ENVTL. L. & PRAC. 53 (2005).

farmers, which determine what can and cannot be done by the farmers.[160] Applying liability to the producers is, thus, similar to applying liability to those who benefit the most from an activity and those who are in a better position to control the activity.[161]

The discussions above show that the desirability of channeling requires a balanced analysis whereby the pros and cons of channeling need to be taken into account. Channeling might be a poor tool for inducing the potential injurer to take necessary preventive measures. However, the absence of channeling might prevent the victims from staging their claims against the producers of the damaging GMOs. After all, the cases showed that plaintiffs (suffering losses resulting from GMOs) are apparently expected to bring their claims against all potential farmers who could have used the GMO. This not only can create high costs (litigation) for the plaintiff, but may also mean that the manufacturer will escape the clutches of the law. Without the possibility of being held liable, or when such a possibility is decreasing, one may expect that the producers' incentives to take preventive actions will also decrease.

A disadvantage of channeling is that it would lead to an exclusive liability of the manufacturer, removing liability from all other parties who also could have affected the accident risk (more particularly the GMO farmers who, through their planting methodology, could also affect the risks of commingling and admixture). However, the current absence of channeling should not in all cases bar the victims' claims against the producers of GMOs whenever they can prove that the damage is caused by the release and planting of GMOs. Accordingly, liability rules should be interpreted in such a way that they can be applied not only against those who use or plant GMOs but also against those who produce and market GMOs in the first place. In this regard, the *StarLink* litigation is a good example of how the liability rules are indeed applicable to GMO producers.

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160. It is a common practice in the use of GM crops for farmers to sign agreements with the producers about how to use the crops, such as those in Monsanto's Technology Use Agreement (TUA). These agreements indicate that the producers, to some extent, still retain their control over the conduct of their client farmers. The farmers, for example, are prohibited from saving, reselling, or even sharing the GM seeds with other farmers. The agreements may also include instructions and directions on how to use the seeds properly. For this reason, Black & Wishart argue that "contrary to Justice Smith's holding in Hoffman, Monsanto does exercise control over whether, where, and how its products are cultivated and reproduced, and substantially removing such control from its client farmers . . . it is abundantly clear that Monsanto intends that its transgenic products and their progeny, in their animate form, should remain firmly under its control at every step of their lifespan." Black & Wishart, *supra* note 59, at 420-21.

161. De Beer concludes that the relationship between GMO producers and their client farmers is similar to the relationship between a landlord and his tenant. Hence, de Beer argues, imposing liability on GMO producers constitutes the application of vicarious liability, in which those who are in a better position to take care or have control over a person or object are liable if such a person or object creates harm to others. Jeremy de Beer, *supra* note 58, at 293.

VI. DEFENSES

A. FORCE MAJEURE

A traditional defense accepted in almost every liability regime is force majeure (although it may have different interpretations). From an economic point of view, one can easily argue that in the case of force majeure there should be no liability. Force majeure is generally a condition, not only for fault or strict liability, but for every liability in tort. It is related to the blameworthiness requirement, which requires that the injurer should have capacity for tortious liability. A tort will indeed, according to most legal systems, only make an injurer liable if the wrongful act is imputable to him.

This condition of blameworthiness relates to the free will and the capacity of discretion of the tortfeasor.[162] This blameworthiness requirement also has a clear economic rationale. When the injurer does not act out of free will, liability cannot influence his incentives to take care and has, therefore, no economic meaning. A finding of liability that does not influence the incentives of the tortfeasor will only create administrative costs (caused by the transfer of the loss) without any compensating benefits in providing additional incentives to take care.

We refer here to the blameworthiness requirement simply as meaning that the injurer contributed in some way to the loss. The requirement of 'blame' traditionally fits into a fault or negligence concept. In fact, in the context of strict liability, mere causation suffices. But if the injurer did not "cause" the accident, he should not be held (strictly) liable. *Force majeure* therefore should remain a defense, even under strict liability, because a finding of liability makes no sense if the injurer could not have influenced the risk.

B. DEVELOPMENT RISK

An important question, also with respect to GMO damage, is of course whether the operator handling GMOs should be allowed to call on the development risk defense. This would mean that the operator would not be liable if the damage could, according to the state of the technology at the time when the act took place, not be foreseen.[163] One would thus assume that an operator is handling GMOs and that certain negative consequences of GMOs for third parties could at that particular moment not be foreseen by the operator. How should, from an economic perspective, the law deal with situations where either the risks change,

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162. Michael G. Faure, *Economic Analysis of Fault*, *in* UNIFICATION OF TORT LAW: FAULT 311, 322 (Pierre Widmer ed., 2005).

163. This is also the formulation chosen in the European Directive on Product Liability of July 25, 1985: liability is excluded if the producer can prove that, having regard to the circumstances, it is probable that the defect did not exist at the time when the product was put into circulation. Council Directive 85/374/EEC, art. 7(b), 1985 O.J. (L210) 29.

or technology changes, and the standard of care increases as a result?

One could argue that holding a person liable for an unforeseen damage will not provide an incentive for an injurer to take more care, because unforeseeability means that the injurer's subjective perception of the probability of the occurrence of the damage is zero. In this case, although the injurer has to pay infinite damages, his expected damage remains zero because the subjective probability of the damage is zero; and hence his optimal care is also zero. In this regard, holding an injurer liable for the unforeseen damage could actually reduce social welfare.

However, one may argue that exposing an injurer to liability, regardless of the unforeseeability of the damage, is efficient as it will induce the injurer to acquire information in order to prevent the damage. In addition, with regard to the GMOs case, one could also argue that although the exact magnitude of damage might be uncertain, the risk of damage caused by GMOs is a real threat.[164] In this regard, Repp argues that GM crop planting is usually undertaken with the contractual obligation to establish a buffer zone, implicitly showing recognition about at least the possibility of cross-pollination, but other types of damages cannot be excluded either. Hence, unforeseeability of GMO damage is relatively hard to argue.[165]

Consequently, it would be simply too easy to state that the tortfeasor will only be held to comply with the "old" standard of care and will never be liable for risks he could not foresee. Indeed, it has equally been stated in the literature that the foresight that there may be liability *ex post* will obviously give incentives to obtain information about risk to industrial operators.[166]

The possibility of *ex post* liability even if technology changes is one of the powerful arguments made in law and economics in favor of liability for the so-called development risk. This should give an operator appropriate incentives for investments in research to acquire information about risk and about optimal

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164. Ellstrand provides several conclusions with regard to gene flow from GM to non-GM crops. First, mating between crops and their wild relatives is common. In this case, mating between GM crops and non-GM relatives is also possible. Second, gene flow does not necessarily lead to serious impacts. Third, natural hybridizations may lead to the problems of increased weediness and invasiveness of some unwanted plants. Fourth, natural hybridizations may also lead to the risk of extinction of wild relatives. Fifth, gene flow varies both between species and within species. Sixth, gene flow may occur at high rates and over high distances. *See* Ellstrand, *supra* note 20, at 1166-1168.

165. Richard A. Repp, *Biotech Pollution: Assessing Liability for Genetically Modified Crop Production and Genetic Drift*, 36 IDAHO L. REV. 585, 615 (2000). A similar opinion has been advanced by Endres, who argues that the possibility of cross-pollination is supported by some studies showing that transgenic pollen may be carried by vectors to a great distance even beyond the buffer zone. *See* Endres, *supra* note 84, at 487. Lewis also shares this opinion by arguing that when released into the environment, GM crops may cross-pollinate with other plants due to wind or animal pollinators; therefore, so the author argues, the risk of cross-pollination "is almost guaranteed." Stephen Kelly Lewis, *"Attack of the Killer Tomatoes?" Corporate Liability for the International Propagation of Genetically Altered Agricultural Products*, 10 TRANSNAT'L LAW 153, 186 (1997).

166. *See generally* Steven Shavell, *Liability and the Incentive to Obtain Information About Risk*, 21 J. LEGAL STUD. 259 (1992); *see also* Steven Shavell, *On Optimal Legal Change, Past Behavior, and Grandfathering* 37 J. LEGAL STUD. 37 (2008).

technologies to prevent the risk.

The question, however, arises whether this reasoning can also be used to justify a retrospective change of a liability rule or changes in the standard of care itself. The argument is hence a completely different one if both the nature of the risk and the liability rule change. The economics of tort law assumes that future incentives for prevention will be affected, given the legal regime in force. Hence, it is hard to argue that an *ex post* change in the liability rule will positively affect the incentives for proper behavior that was not considered wrongful at the time the act was committed by the industrial operator. One can expect an operator to assume that new risks may emerge, but hardly that the contents of the law will change. Requiring this would lead to an inefficiently high demand for preventive measures and thus to over-deterrence. Thus, retrospective liability indeed seems problematic, taking into account the deterrent function of tort law.

From this it follows that there is a dilemma: on the one hand it is useful that the standard-setting process in civil law is seen as a process of learning whereby the standard of care is not static, but dynamically changes in time.[167] It would be wrong to state that due care standards should never change. There may be many reasons, for instance, new technological insights, leading judges to the efficient decision that a more stringent standard of care can be applied. This new case law can, moreover, have an important signaling function for other parties in the market, who can again, adapt their future behavior. But the question obviously arises: what should be done with the individual defendant in the particular case in which a new standard of care is set? Should we sacrifice him for the benefit of a more efficient standard in the future, and make him retroactively liable, although his behavior was not considered wrongful at the time when it was committed? There is a possible way out of this dilemma presented by—*inter alia*—the German Supreme Court.[168] In that particular case, the Supreme Court held that an operator violated a general duty of care given the fact that technology had changed. However, at the same time, the Court also held that the operator was not to blame for the violation of the duty of care, since this was not foreseeable.[169] This approach is known in the American literature as the "prospective overruling," meaning that a court follows an old duty of care in a particular case (with the result that there is no finding of liability), but announces that it will follow a different decision in the future.[170] This seems to be both an efficient and a just

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167. This argument has been powerfully stressed by Claus Ott & Hans-Bernd Schäfer, *Negligence as Untaken Precaution, Limited Information, and Efficient Standard Formation in the Civil Liability System*, 17 INT'L REV. L. & ECON. 15, 15 (1997).

168. *See* Bundesgerichtshof [BGH] [Federal Court of Justice] Oct. 23, 1984, NEUE JURISTISCHE WOCHENSCHRIFT [NJW] [16-20], 1985 (Ger.).

169. *Id.*

170. This has been defended in Dutch legal literature by O. Haazen, *De temporele werking van een rechterlijke uitspraak*, *in* DE ROL VAN DE RECHTER IN DE MODERNE WESTERSE SAMENLEVING 171 (Schermers, Bellekom & Van Kampen eds.,1993).

solution. On the one hand, a preventive effect is achieved for the future since future potential tortfeasors know that a new and more stringent due care standard will apply. On the other hand, it seems fair not to apply this new standard with respect to the particular defendant in that particular case, who could not have known that new rules would apply.

In sum, the discussion above makes clear that in fact a distinction has to be made (although the issues seem to be confounded sometimes) between on the one hand, a retrospective application of a new liability regime, and on the other hand, the liability for development risks. A liability regime for risks that are not yet known today is not necessarily inefficient, precisely because, if this is known in advance, it will give incentives to require information on these new risks and on the optimal techniques to prevent the risk. Thus a strict liability, also for development risks, might provide appropriate incentives for a dynamic investment in optimal preventive techniques. This however does not justify a retroactive application of new standards or new legislation, which could never have positively affected future incentives for prevention. In other words, a liability for development risks is not inefficient as long as it may positively influence incentives for prevention and as long as the development risk liability is not a disguised retroactive liability.[171]

The justified fear of retroactivity probably explains why legal systems are often reluctant to introduce liability for development risks. For instance, in the context of the Product Liability Directive, we can point to Article 7(b), which explicitly excludes liability if the producer can prove that, having regard for the circumstances, it is probable that the defect did not exist at the time when the product was put into circulation.[172] Moreover, the real "state-of-the-art defense" is included in Article 7(e), which states that the producer shall not be liable if he can prove that the state of scientific and technical knowledge at the time he put the product into circulation was not such as to enable the existence of the defect to be discovered.[173] However, Article 15.1(b) provided for an option for member states to nevertheless introduce liability for development risks.[174] This option was only adopted by Luxembourg and Finland.[175]

As explained earlier, the foreseeability requirement could be relaxed so long as

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171. A similar conclusion concerning the efficiency of a development risk defense is reached by Gerhard Wagner, *Haftung und Versicherung als Instrumente der Techniksteuerung*, VERSICHERUNGSRECHT 1450 (1999).

172. Council Directive, *supra* note 163, at art. 7(b).

173. *Id.* at art. 7(e). The state of the art defense has also been addressed in the American context by Boyd & Ingberman who show that the customary practice test tends to induce inadequate safety, whereas the technological advancement test tends to induce excessive safety. James Boyd & Daniel E Ingberman, *Should "Relative Safety" Be a Test of Product Liability?*, 26 J. LEGAL STUD. 433, 433 (1997).

174. Council Directive, *supra* note 163, at art. 15.1(b).

175. A similar option was adopted by Spain for food and medical products as well as by France for products derived from the human body. See the overview of the transposition in domestic law, provided in the *Commission Green Paper on the Liability for Defective Products*, at 35-36, COM (1999) 396 final (July 28, 1999).

it does not constitute a disguised retroactive liability. It should also be noted here that the issue of foreseeability of damage resulting from GMOs requires an analysis of the possible impacts of GMOs. Some impacts will occur with a high level of certainty, while others may not. Such different levels of certainty inevitably merit special attention in the discussion of foreseeability.

C. THE FORESEEABILITY REQUIREMENT AND POSSIBLE IMPACTS OF GMOS

Various studies summarized in Section II function as early warnings regarding the possible impacts of GMOs. In addition, those findings might also serve as critiques against the safety claims of GMOs. However, despite such findings, some still argue that the impacts of GMOs are still uncertain. In this case, it should be noted that any concern or finding regarding the impacts of GMOs seems to have counter-arguments; such arguments may take several forms. They may point to the low probability of the impacts of GMOs.[176] They could also take the form of arguments against the magnitude of the impacts by showing that the impacts will be rather limited or isolated.[177] Others may simply point out that the risks posed by GMO crops are similar to those posed by non-GM crops.[178] Taking into account these opposing views, one might argue that scientific evidence about the possible impacts of GMOs is not conclusive. When damage does occur in the future, these arguments will certainly serve as a reason to show that some damage was still scientifically unforeseen at the time of the release of GMOs.

Whether the level of scientific information available today constitutes evi-

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176. The study of Chévre et al., for example, observes that under natural conditions, gene flow from GM canola to its wild relatives is very rare and occurs only at a slow rate. Hence this indicates that the probability of this GM crop is actually low. *See* Anne-Marie Chévre et al., *Gene Flow from Transgenic Crops*, 389 NATURE 924, 924 (1997).

177. Some studies, for example, have also found some results contrary to the study of Losey et al., *supra* note 36, concerning the impacts of Bt crop on Monarch butterfly. These studies point to some methodological flaws in the Losey et al.'s study to indicate that the study did not place under natural conditions. In addition, they also show that GM corn pollen actually contains much less Bt toxin compared to that used by Losey et al. Based on these grounds, these studies conclude that the impacts of GM crops on Monarch butterfly are negligible. *See* Jean-Pierre Wisniewski et al., *Between Myth and Reality: Genetically Modified Maize, an Example of a Sizeable Scientific Controversy*, 84 BIOCHIMIE 1095, 1099-1100 (2002); J. Kim Kaplan, *Bt Corn not a Threat to Monarchs*, 50 AGRICULTURAL RESEARCH 16, 16 (2002); Mark K. Sears et al., *Impact of Bt Corn Pollen on Monarch Butterfly Populations: A Risk* Assessment, 98 PROC. OF NAT'L ACAD. OF SCI. 11937 (2001); John Hodgson, *Monarch Bt-Corn Paper Questioned*, 17 NATURE BIOTECHNOLOGY 627 (1999).

178. Conner and colleagues, for example, argue that the problems of crop-to-wild hybridizations and their impacts are not new in agriculture, and cannot be associated only with GMOs. Because the hybridizations are equally likely to occur both via GM or non-GM crops, the problem of hybridizations should be resolved based on an agricultural strategy equally applied both to GM and non-GM crops. The authors hence argue that the impacts will not be more severe and catastrophic than those resulting from non-GM crops. Similarly, they also argue that some possible impacts such as the effect on non-target organisms, are familiar and inherent not only with GMOs, but also to all existing agricultural practices. Anthony J. Conner et al., *The Release of Genetically Modified Crops into the Environment, Part II: Overview of Ecological Risk Assessment*, 33 THE PLANT J. 19, 28-31 (2003).

dence to indicate the foreseeability of some damage will depend on how the courts interpret the foreseeability standard. This will eventually depend on the courts' interpretation of the level of scientific certainty regarding the impacts of GMOs.

In this regard, Khoury and Smyth argue that based on the current approach applied by the courts in considering the foreseeability requirement, the seed companies are likely to succeed in exercising the unforeseeability defense by resorting to the current uncertainties concerning the impacts of GMOs. The more uncertain the impact, the more likely that the company will escape liability.[179] To avoid this situation, Khoury and Smyth have proposed the incorporation of the precautionary principle into liability. They argue that by applying this principle, the courts will be induced to take into account the current concerns of the impacts of GMOs. This means that the foreseeability requirement will be somehow relaxed to allow the courts to appreciate public concerns regarding the impacts of GMOs. They argue that when the principle is incorporated into the liability system, "acting in accordance with the prevailing levels of knowledge would no longer exonerate an individual who could be held liable for omitting to foresee and prevent risks that although unconfirmed may bring about injury in the future."[180]

D. LIABILITY BASED ON THE PRECAUTIONARY PRINCIPLE FOR GMOS?

Khoury's and Smyth's proposal of incorporating the precautionary principle into liability is similar to Treich's and Gollier's opinion. They argue that in the face of uncertainty, the threat of liability will prevent strategic behavior of competitive firms that otherwise will exploit the uncertainty of the damage of their products in order to gain market control for the products. In this case, firms will market their innovations as soon as possible without considering the possible impacts of the innovations. Incorporating the precautionary principle into liability thus means that despite current uncertainties concerning some impacts of GMOs, GM operators will be held liable if these impacts materialize and their GM products turn out to be toxic.[181]

This section will not discuss whether the proposal of incorporating the precautionary principle into tort is justifiable.[182] Instead, this section attempts to

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179. Khoury & Smyth, *supra* note 48, at 226.

180. *Id.* at 228.

181. Gollier & Treich, *supra* note 130, at 98; Nicolas Treich, *What is the Economic Meaning of the Precautionary Principle?*, 26 GENEVA PAPERS ON RISK & INS. 334, 342 (2001). This discussion on the value of the precautionary principle is of course strongly related to the foreseeability requirement in liability law, just discussed.

182. It should be mentioned here that the proposal may run against the purpose of the precautionary principle. Craik and colleagues for example argue that the use of the principle in tort law may not be in line with the democratization of the decision making process, which constitutes an important message of the principle.

discuss the possible cost to the GM operator when such a proposal is implemented.

At first glance, one may disagree with the incorporation of the precautionary principle into tort law because the incorporation will make an injurer liable for unforeseeable damage. Holding the injurer liable for unforeseeable damage will not alter the injurer's level of care because the injurer has already underestimated the damage. Shavell, who interprets unforeseeability as a situation in which the injurer has subjectively underestimated the probability of damage, argues "inclusion of accident in the scope of liability would not have any effect on the injurer's behavior—for his behavior is determined by his probability."[183] The incorporation of the precautionary principle into liability rules is intended exactly to remove the foreseeability requirement of liability rules. According to Pardy, the application of the precautionary principle in tort law serves not only to remove the requirement of fault, but also the requirement of foreseeability.[184] The authors conclude that "the precautionary principle is essentially a renunciation of foreseeability as a relevant consideration."[185] The application of the precautionary principle to tort law therefore means that applying strict liability and, simultaneously, removing the requirement of foreseeability from strict liability.[186] The intended result of such an application would be to force the potential injurer to increase his subjective probability of an accident. In other words, the injurer should err on the side of safety. The overestimation of probability is, thus, preferable to the underestimation of probability.

In our view, incorporating the precautionary principle into tort law may take two different forms. First, it may take a negligence standard in which the failure to comply with the precautionary regulatory standard will result in liability. In this case, the principle is indirectly incorporated into liability in such a way that the regulatory standard follows the precautionary approach and non-compliance with the standard will constitute liability. Second, the defendant will be held liable for any damage because the damage has itself constituted evidence that the defendant has failed to take the precautionary measures to prevent the damage.

To answer the question of which of these possible applications will impose the highest cost on individual GM operators, one certainly needs some empirical

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They argue that unlike the policy makers, the courts may lack the capacity to address the issue of uncertainty. Accordingly, they often have to rely on conflicting testimonies. More importantly, the precautionary principle requires the democratization of the decision making process, such as broad public consultation and participation. And this process cannot to be done by the courts. Neil Craik et al., *Genetically Modified Crops and Nuisance: Exploring the Role of Precaution in Private Law*, 27 BULL. SCI. TECH. & SOC'Y 202, 211-212 (2007).

183. *See* Shavell, *supra* note 122, at 490.

184. Bruce Pardy, *Applying the Precautionary Principle to Private Persons: Should it Affect Civil and Criminal Liability?*, 43 LES CAHIERS DE DROIT 63, 66-67 (2002).

185. *Id.* at 67.

186. In fact, Pardy criticizes strict liability applied according to the Rylands and Fletcher rule as a form of strict liability that is less fault-based (because it does not require fault) but is not truly strict (because it still requires foreseeability.) *Id.* at 68.

research. However, we could expect that the costs for the first and second option are somewhat different. This is because under the first option, the operator will meet the regulatory standard in order to avoid liability. Because such a standard has incorporated the precautionary principle, in the sense that it is established to prevent some possible impacts, although those impacts are not yet conclusive, the cost incurred by the operator is the cost of complying with such a precautionary standard. When the standard of care is left to the operator, the cost will still be the same since the operator will also take a level of care that may prevent the damage, which is currently still uncertain. In this situation, the standard literature on the choice between the negligence rule and strict liability will apply, in the sense that both systems will induce the potential injurer to take a similar level of care.[187]

The level of care taken by the operator will be different under the second option, in which the operator will be held liable for any damage simply because the damage is considered a proof indicating the operator's failure to take precautionary measure in order to prevent the damage. If this option is implemented, the operator will be forced to consider all damage, whether or not it is foreseeable. In this situation, at least the operator is induced to continue increasing its investment in safety in order to avoid the damage. The cost of taking such measures will certainly be higher compared to the compliance cost under the first approach.

The result above can be seen in the explanation below.

Assume that the operator of GMOs has already taken some preventive measures in accordance with various regulatory standards. Under the first option, in which the non-compliance with the precautionary regulatory standards results in liability, the operator will have the incentives to take care only up to the level required by the standards. From an economic perspective this means that the injurer will stop taking further care whenever the benefits of not taking a higher level of care, denoted as B, exceed the costs of not taking such a level of care, denoted as C. Formally this is written as to stop taking further preventive measures, whenever:[188]

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187. Standard literature in law and economics shows that both systems will result in a similar situation with respect to the level of care, namely that both will induce the injurer to take the optimal level of care. *See* ROBERT COOTER & THOMAS ULEN, LAW & ECONOMICS 300-308 (3d ed. 2000).

188. Following Farrow and Hayakawa, the default action in this assumption is to take further preventive measures, which will stop only when the benefits of not taking further preventive measures are lower than the costs. According to Farrow and Hayakawa, this assumption about the default action follows the shifting in the burden of proof as an element of the precautionary principle. *See* Scott Farrow & Hiroshi Hayakawa, *Investing in Safety: An Analytical Precautionary Principle*, 33 J. OF SAFETY RESEARCH 165, 168 (2002). Authors seem to agree that the precautionary principle requires that the burden of proof or persuasion lie on the party who proposes a new technology, or who imposes risks of irreversible harms on others, or who intends not to take safety measures. For discussions about this element of the precautionary principle, see Andy Stirling, *Risk, Uncertainty and Precaution: Some Instrumental Implications from the Social Sciences*, *in* NEGOTIATING ENVIRONMENTAL CHANGE: NEW PERSPECTIVES FROM SOCIAL SCIENCE 33, 51-53 (Frans Berkhout, Melissa Leach & Edward Elgar, ed., 2003); *see also* David Kriebel et al., *The Precautionary Principle in Environmental*

$$B > C,$$

or

$$(B/C) = 1 \tag{1}$$

A question arises whether the operator will have similar incentives for taking a higher level of care if the operator will be held liable for all occurring damage, as is proposed under the second option. Following Farrow and Hayakawa, assume that the benefits of not taking further preventive measures are the avoided compliance cost, which depend on various uncertain factors such as the development of technology.[189] The decision to stop taking further preventive measures is also assumed to be irreversible, in the sense that once the decision is found to be mistaken, it is difficult to correct the decision. The benefits of not taking further preventive measures will increase over time, with the rate of growth α. These uncertain benefits are represented by the level of instabilityσ, and a stochastic component dz_B. Therefore, with the small increase of time, dt, the benefits of not taking further preventive measures will depend on both α and σ, as can be seen in the equation below:

$$dB = \alpha B dt + \sigma B dz_B \tag{2}$$

The cost of not taking further preventive measures is the uncertain damage that presumably results from GMOs. The damage could be irreversible, in the sense that once it occurs, the damage is difficult to control. Since the private decision maker will be held liable for the damage, the costs of not taking further preventive measures might mean the costs resulting from being held liable. The costs of not investing in safety, denoted as C, also depend on the level of instability, represented as λ, and the stochastic component, dz_C. Hence, the differential equation of the costs of not taking further preventive measures is:

$$dC = \lambda C dz_C \tag{3}$$

The objective of the private decision maker is to maximize the discounted expected payoff between continuing and stopping further preventive measures. This maximization can be written as:

$$F(B,C) = E[e^{-\rho t}(B - C)] \tag{4}$$

Science, 109 ENVTL. HEALTH PERSP. 871, 871 (2001).

189. Farrow & Hayakawa, *supra* note 188, at 169.

Following this equation, the optimal time to stop taking further preventive measures is achieved when the ratio between the benefits and costs of not taking further preventive measures exceeds the precautionary multiplier (Γ). In this case, the cost/benefit ratio at optimum time is:

$$(B/C)^* > \Gamma \tag{5a}$$

The value of the multiplier is obtained as:

$$\Gamma = \beta/(\beta - 1)$$

The value of β depends on various factors, such as the discount rate, the level of uncertainty of B and C, and the level of growth in B.[190]

Compared to equation (1), equation (5a) requires a higher threshold for ceasing to take preventive measures. This occurs due to the presence of a precautionary multiplier in equation 5(a).[191] With the presence of the multiplier, the benefits of not taking further preventive measures should be much higher than the costs of not taking such measures. In equation 5(a), the precautionary principle is applied in the form of the precautionary multiplier, which functions to increase the economic requirement for not taking preventive measures.

Comparison between equation (1) and (5a) also indicates that the second option, namely that the operator of GMOs will be held liable for any damage caused by GMOs, will create higher incentives for the operator to continue taking preventive measures. Another interpretation of this comparison will be that the second option imposes higher costs on the operator compared to the first option, because higher a level of care by definition corresponds also to higher compliance costs. This indicates an important message, that the incorporation of the precautionary principle into liability rules should not be done by eliminating the unforeseeability requirement, namely by making the prospective defendants liable for any damage regardless of whether they could previously be expected to foresee the damage or not. Instead, the analysis above indicates that the incorporation serves to increase the standard of care under the negligence rule. This might mean that safety regulations on GMOs should be set in accordance with some possible impacts of GMOs. Non-compliance with such a precautionary regulation should automatically lead to liability under the negligence rule.

E. CONTRIBUTORY NEGLIGENCE

We indicated above that both a strict liability rule and a negligence rule will

190. The appendix of this paper provides a theoretical explanation on Γ and β.

191. It is important to note that the value of Γ should be greater than 1, otherwise the precautionary principle will not have such a multiplying effect.

lead to the optimum in cases where the victim's care does not influence the probability of an accident and where only care (and not the activity level) can influence the risk. Most accident situations are, however, "joint care" cases.[192] In this situation the risk is also influenced by the behavior of the victim. A simple strict liability rule would not lead to the efficient result, since the victim has no incentive to spend on care. To remedy this problem, the victim might be considered "contributorily negligent" if he does not take due care. A contributory negligence rule, as known under common law, excludes a right to compensation for the victim who did not take due care.[193]

Assuming that the legally required level of care of the victim is equal to the efficient level of care, the victim will have the incentive to take optimal care. If she/he did not take due care he would be found negligent and would receive no compensation. An efficient result will also follow both under a negligence rule and under a strict liability rule with a contributory negligence defense. In both cases the injurer will take efficient care and the victim will (being fully exposed to the risk), in order to avoid bearing the loss himself, take efficient care as well. Discussing the economic model of tort law, we therefore indicated that both a strict liability rule, in combination with a defense of contributory negligence and a negligence rule (with or without contributory negligence), will give appropriate incentives to the victim to take efficient care.[194]

A comparative negligence rule has the effect of proportionally dividing the loss between the injurer and the victim, if both committed a fault. Under this rule the right to compensation will be proportionally reduced if the victim was negligent. The injurer will still take efficient care to avoid liability, while the victim still takes care to minimize his own loss.[195] The efficiency of this rule is debated in the literature. Haddock and Curran point to difficulties in analyzing the comparative benefits of comparative negligence versus a contributory negligence defense.[196] It is well known that Posner is an opponent of this rule.[197] According to him, the rule causes considerable administrative costs, without any compensating benefits for the incentives to take care. Not only is an intervention of the legal system necessary to shift a part of the loss from the victim to the injurer, but judges will also have to examine the faults of both parties and the proportion in which they

192. Although we already argued above that environmental pollution is probably a good example of a truly unilateral case.

193. For a recent overview of the economic literature in this respect see Mireia Artigot I Golobardes & Feranado Gómez Pomar, *Contributory and Comparative Negligence in the Law and Economics Literature*, *in* TORT LAW & ECONOMICS 46 (Michael Faure, ed., 2009).

194. *See* John P. Brown, *Toward an Economic Theory of Liability*, 2 J. LEGAL STUD. 323, 340-342 (1973); Calabresi, *supra* note 75, at 663; Landes & Posner, *supra* note 73, at 880-82.

195. David Haddock & Christopher Curran, *An Economic Theory of Comparative Negligence*, 14 J. LEGAL. STUD. 49, 59-63 (1985).

196. *Id.*

197. *See* RICHARD A. POSNER, ECONOMIC ANALYSIS OF LAW 187–89 (5th ed., 1998).

contributed to the loss. Posner argues that comparative negligence makes economic sense only when society wants to use the tort system to provide insurance to accident victims.[198]

In sum, if a strict liability rule is proposed for GMO damage, a defense should be permissible to take account of the behavior of the victim, but this can either be a contributory or a comparative negligence rule. To be clear: a strict contributory negligence rule, meaning that the victim loses the claim on compensation entirely in case of his negligence, is practically no longer applied. Most legal systems have turned to a proportionate reduction of the compensation due to the victim. If on the other hand a negligence rule is applied to GMO damage, it is not strictly necessary to add a contributory negligence defense.[199]

VII. REMEDIES

A. DAMAGES IN TORT

Law and economics scholars usually hold that the amount of damages the injurer should pay should be at least equal to the victim's loss, in order to provide optimal compensation to the injurer.[200] These so-called compensatory damages must be paid to the victim in order to give the victim an incentive to sue, which is essential to letting the tort system provide an effective and credible deterrent. The duty to pay compensatory damages to the victim will, moreover, prevent the victim from taking inefficiently high precautions.[201] If the damages to be paid by the injurer would fall short of the harm, so that the expected payments would be below expected harm, the incentives to reduce the risk would be inadequate.[202]

Therefore, the starting principle should be that the liable party should pay for the actual level of loss the victim.[203] There is extensive economic literature on the

198. RICHARD A. POSNER, ECONOMIC ANALYSIS OF LAW 175 (7th ed., 2007).

199. A contributory negligence defense may arise, for example, in the form of the infringement of patent right of a GM crops producer. We could refer to the *Monsanto v. Schmeiser* case, in which the defendant has been found guilty of the infringement of Monsanto's patent rights for herbicide-resistant canola. *See* Jeffrey L. Fox, *Canadian Farmer Found Guilty of Monsanto Canola Patent Infringement*, 19 NATURE BIOTECHNOLOGY 396, 396 (2001), *available at* http://www.nature.com/nbt/journal/v19/n5/pdf/nbt0501_396.pdf (last visited Jan. 17, 2011). The ruling has, however, been severely criticized as the court ignores the fact that the defendant did not use glyphosate, an herbicide to which the patented GM canola is supposed to resist. Some authors argue that if the possession of hybrids containing the patented gene is already a sufficient ground for defendant liability for the infringement of a patent right, then the question of the defendant's intention should be seriously considered by the court. Otherwise, a farmer whose land has been contaminated by GM crops and who, unwillingly grows the hybrids, will be found guilty for the patent infringement. *See* Maria Lee & Robert Burrell, *Liability for the Escape of GM Seeds: Pursuing the 'Victim'?*, 65 MOD. L. REV. 517, 523 (2002); *see also* Preston, *supra* note 14, at 1167-69.

200. RICHARD A. POSNER, ECONOMIC ANALYSIS OF LAW 192 (6th ed., 2003).

201. *Id.*

202. STEVEN SHAVELL, FOUNDATIONS OF ECONOMIC ANALYSIS OF LAW 236 (2004). For a recent overview *see* Louis E. Visscher, *Tort Damages*, *in* TORT LAW AND ECONOMICS 153-200 (Michael Faure ed., 2009).

203. SHAVELL, *supra* note 202, at 237.

question of how life should be evaluated in a tort case, and more particularly, on the valuation of non-pecuniary losses.[204] In addition, economists hold that in some cases damages should outweigh a low probability of detection and should therefore be "punitive." The punitive damages are thus meant to provide appropriate incentives to an injuring party, in a case where, for instance, through his malicious acts, the probability of the tort being detected would be lower than one.[205]

A highly debated issue in the law and economics literature, and an important issue for damage caused by GMOs, is the extent to which damages should be awarded for so called pure economic loss.[206] Economic analysis has provided explanations for the traditional denial of compensation for pure economic loss in many legal systems. An important explanation is that an economic loss would merely lead to a private loss for the victim, but not necessarily to a loss for society (a so called social loss).[207] Compensation of an economic loss that would not at the same time constitute a social loss would thus, from an economic perspective, lead to a waste of administrative costs.[208] A problem is, however, that today certain differences exist between legal systems concerning the recoverability of pure economic losses. More recent economic literature still holds that as long as a damage does not lead to a social loss, but only a personal loss, the traditional denial of compensation can be justified.[209] However, the large differences between the legal systems as far as compensation of economic loss is concerned cannot be fully explained on economic grounds.[210]

B. INJUNCTION

There is still another question that could be asked in relation to the remedies. What if the potential victim sees the harm coming or has a case where harm continues? Can injunctive relief be sought so that the judge can order the injurer to refrain from the damaging behavior? In this particular case it could mean that specific measures are ordered by the judge to the injurer to avoid further damage resulting from the GMO.

Regarding injunctive relief, the economic literature makes a distinction between the way property rights are protected and the way other rights are protected. Economists point to the fact that the typical remedy in case of a

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204. Visscher, *supra* note 202, 163-65.

205. For an overview of the economics of punitive damages see A. Mitchell Polinsky & Steven Shavell, *Punitive Damages*, *in* TORT LAW AND ECONOMICS 228-44 (Michael Faure ed., 2009).

206. For an excellent economic account see Giuseppe Dari Mattiacci, *The Economics of Pure Economic Loss and the Internalization of Multiple Externalities*, *in* 9 TORT AND INSURANCE LAW, PURE ECONOMIC LOSS 167-90 (Willem H. van Boom et al. eds., 2004).

207. *Id.*

208. *See* MAURO BUSSANI & VERNON V. PALMER, PURE ECONOMIC LOSS IN EUROPE (2003).

209. *See* Jef De Mot, *Pure Economic Loss*, *in* TORT LAW AND ECONOMICS 201-14 (Michael Faure ed., 2009).

210. *Id.*

violation of a property right is an injunction.[211] Damages are the usual remedy for torts, whereas injunction is the usual remedy in case of a nuisance (violation of a property right).[212] For the case of GMOs this would mean that when a neighbor's property right (enjoying a non-GM crop) would be endangered by the presence of a neighbor using GMO, economists would thus predict that the remedy would be injunctive relief. However, the fact that a property right is granted and that the victim could theoretically use injunctive relief does not necessarily mean that this will be the result. The Coase theorem[213] predicts that parties may engage in bargaining, and when transaction costs are low, this is precisely what will happen. Hence, the injurer may "buy" his right to pollute by paying damages to the victim. This would of course depend on the potential efficient outcome. But the Coase theorem holds that if transaction costs are equal to zero, successful bargaining can cure inefficient laws. Hence, economists consider damages and injunctions as equally efficient remedies when transaction costs equal zero.[214] Differences in efficiency thus depend on transaction costs.[215] If transaction costs are high then bargaining may be impossible. In that case, the more efficient remedy would be damages and not the injunction. The injunction could result in an inefficient solution, whereas damages could be adjusted to harm done. Precisely because in a nuisance context where a property right protection is enforced, transaction costs are relatively low, the typical remedy will be the injunction. The injunction is particularly more efficient than damages when the parties can bargain with each other. The reverse is thus true in a high transaction costs setting, which is typically the tort case. Then economists would predict that the efficient remedy should be damages and not injunctive relief. This is a finding in a well-known paper by Calabresi and Melamed, which is often quoted in the law and economics literature.[216] They argue as follows:

> When there are obstacles to cooperation (high transaction costs), the more efficient remedy is the award of compensatory money damages;
> When there are few obstacles to cooperation (low transactions costs), the more efficient remedy is the award of an injunction against the defendant's interference with the plaintiffs' property.[217]

They therefore hold that when the nuisance is private and thus few parties are affected by it the costs of bargaining will be low and the injunction may be the

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211. Guido Calabresi & A. Douglas Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARV. L. REV. 1089 (1972).

212. *See* ROBERT COOTER & THOMAS ULEN, LAW & ECONOMICS 100 (4th ed. 2003).

213. *See generally* Coase, *supra* note 74, at 1.

214. *Id.* at 144.

215. Cooter & Ulen, *supra* note 212, at 104.

216. Calabresi & Melamed, *supra* note 211.

217. *See* Cooter & Ulen, *supra* note 212, at 104-107.

preferred remedy.[218] This then prevents the court from undertaking the difficult job of computing damages. The injunction in this law and economics perspective is, however, not viewed as a remedy that would forever prohibit the offensive activity, but it is viewed as an instruction to the parties to resolve their dispute through bargaining. In the case of harmful externalities to third parties where bargaining is often impossible because of high transaction costs, damages will be the more efficient remedy. Cooter and Ulen therefore hold that in choosing between injunctions and damages the court will have to examine the number of people affected by the externality. Only when the number of affected parties is low (this can often be the case with GMO damage) may injunctive relief be warranted.[219]

If the court, however, tends to apply a permanent injunction and damages, the results may be different. The court should consider the social value of GM crops compared to the harms suffered by non-GM crops farmers. In this case, the court might look at the benefits of GM crops in general, ranging from increasing productivity to serving as a solution to provide cheap and nutrition-rich food for the world. These benefits should, of course, be compared with the perils of GM crops and with the needs to provide non-GM products as an alternative for society. In particular, the benefits to individual GM farmers may be compared with the damage suffered by individual non-GM farmers. If the value of GM crops exceeds the harms suffered by non-GM farmers, then permanent damages are a preferable remedy. This is because, as the potential Pareto criterion suggests, efficiency means that the winner still gains after compensating the loser, and because GM crops, which are highly beneficial to society, are too important to be permanently stopped. An injunction to stop the use of GM crops may in that case be inefficient.

C. FINANCIAL CAPS?

A further question that could be asked, as far as damages and remedies are concerned is whether there is any argument to putting a financial cap or limit on the amount of damages due to the victim. To answer this question, again a distinction has to be made between the contracts case (where *ex ante* bargaining is possible) and the tort case (where the victim is a third party and hence bargaining is impossible). In the case of a contract, parties could of course agree *ex ante* to limit damages due to a specific amount which could be less than the actual loss suffered by the victim. If that were the case it would be an explicit agreement concerning allocation of risk which would undoubtedly also have an effect on the price agreed between the parties. In that particular case, there could be no objection against a limit. In fact, it amounts to liquidated damages, an

218. *Id.*
219. *Id.* at 168-69.

amount of damages *ex ante* agreed by the parties in case of breach of contract.

A limitation of liability is far more complicated in the tort case. In the literature, it has been indicated that there may be good reasons to favor a strict liability rule for major industrial accidents,[220] the main reason being that only a strict liability rule would lead to a full internalization of those highly risky activities.[221] This strict liability rule is especially put forward in a so-called unilateral accident situation, where only one party influences the accident risk. Only with strict liability would the potential injurer also have an incentive to adopt an optimal activity level. This full internalization is obviously only possible if the injurer is effectively exposed to the full costs of the activity he engages in, and is therefore in principle held to provide full compensation to a victim.

An obvious disadvantage of a system of financial caps is that it would seriously impair the victim's rights to full compensation. If the cap is indeed set at a much lower amount than the expected damage, it would not only violate the victim's right on compensation, but the above-mentioned full internalization of the externality would not take place either. From an economic point of view, a limitation of compensation poses a serious problem, because there will be no internalization of the risky activity. Indeed, if one believes that the exposure to liability has a deterrent effect, a limitation of the amount of compensation due to victims poses another problem. There is a direct linear relationship between the magnitude of the accident risk and the amount spent on care by the potential polluter. If the liability, therefore, is limited to a certain amount, the potential injurer will consider the accident as one with a compensation ceiling. Hence, he will spend on taking care to avoid an accident caused with a magnitude equal to the limited amount, and he will not spend on the care necessary to reduce the total accident costs. Obviously, the amount of care spent by the potential injurer will be lower and a problem of under-deterrence arises. The amount spent on optimal care, reflected in the optimal standard, as the care necessary to reduce the total accident costs efficiently, will be higher than the amount the potential injurer will spend to avoid an accident equal to the limited amount.[222] Thus, as a result of the cap, too little care would be taken.[223]

The conclusion, however, is different in the case of bilateral accidents, where

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220. Above, we argued that it will depend upon the specific circumstances of the case whether there is an argument in favor of strict liability for GMO damage. A crucial factor in that respect is the respective contribution of both injurer and victim to the risk of GMO mixture. We therefore assume here that the influence of the injurer is more important and that, therefore, the legal system has adopted a strict liability rule.

221. Shavell, *supra* note 75, at 8; Shavell, *supra* note 123, at 603.

222. *See* Michael Faure, *Economic Models of Compensation for Damage Caused by Nuclear Accidents: Some Lessons for the Revision of the Paris and Vienna Conventions*, 2 EUR. J.L. & ECON. 21 (1995).

223. The reason for the underdeterrence is the same as for the underdeterrence that results from the insolvency of the injurer. Underdeterrence arises because the injurer is not exposed to full liability, either as a result of his insolvency or as a result of a cap.

the victim's behavior may also affect the accident risk. The standard argument against providing full compensation to victims (also of non-pecuniary losses) in the case of bilateral accidents is that victims can take precautionary measures which are not always observable for judges and which can therefore not be fully accounted for in contributory or comparative negligence defenses.[224] A limit on the compensation in the case of bilateral accidents may, therefore, be useful in cases where victims should be given additional incentives to reduce the accident risk. Whether caps are efficient in specific bilateral accident cases will depend on the circumstances. The question arises—*inter alia*—whether exposing the victim to risk is indeed necessary to provide these additional incentives or whether the victim's incentives can be optimally controlled via the contributory negligence defense. Also, the amount of the cap remains important. If the cap were set too low, it would give incentives to the victim, but it could equally lead to serious under-deterrence of the injurer.

D. COMPULSORY INSURANCE?

Another question is of course whether there is an economic argument to force a potentially liable GMO producer to seek insurance coverage. This, again, is an issue that has received a significant amount of attention in the law and economics literature. We will of course not summarize all of this literature within the scope of this study, but merely state the most important argument in favor of compulsory insurance from an economic perspective.[225] The most important argument for introducing compulsory liability insurance relates to the insolvency problem. The argument goes that the magnitude of the harm will often exceed the individual wealth of an injurer, whereby a problem of under-compensation of victims will arise. Hence, lawyers would push forward compulsory insurance as an argument for guaranteeing an effective compensation to the victim.

It is, however, also possible to make an economic argument that insolvency will lead to under-deterrence problems, which may be remedied through liability insurance. Indeed, this so-called "judgment-proof" problem has been extensively dealt with in the economic literature.[226] If the expected damage largely exceeds the injurer's assets the injurer will only have incentives to purchase liability insurance up to the amount of his own assets. He is indeed only exposed to the

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224. This point has been made by Samuel A. Rea, Jr., *Nonpecuniary Loss and Breach of Contract*, 11 J. LEGAL STUD. 35, 505-52 (1982); Michael Adams, *Warum kein Ersatz von Nichtvermögensschäden, in* ALLOKATIONSEFFIZIENZ IN DER RECHTSORDNUNG, 214 (Claus Ott & Hans-Bernd Schäfer eds., 1989), Claus Ott & Hans-Bernd Schäfer, *Schmerzensgeld bei Körperverletzungen, Eine ökonomische Analyse*, JURISTENZEITUNG, 564-565 (1990). *See also* Michael Faure, *Compensation of Non-pecuniary Loss: An Economic Perspective, in* EUROPEAN TORT LAW, LIBER AMICORUM FOR HELMUT KOZIOL 143-159 (Magnus & Spier eds., 2000).

225. For a more detailed discussion *see* Michael Faure, *Economic Criteria for Compulsory Insurance*, 31 GENEVA PAPERS ON RISK AND INSURANCE 149, 149-68 (2006).

226. *See generally* Steven Shavell, *The Judgment Proof Problem*, 6 INT'L REV. L. & ECON. 43, 43-58 (1986).

risk of losing his own assets in a liability suit. The judgment-proof problem may, therefore, lead to under-insurance and thus to under-deterrence. Jost has rightly pointed out that in these circumstances of insolvency, compulsory insurance may provide a better outcome.[227] By introducing a duty to purchase insurance coverage for the amount of the expected loss, better results will be obtained than with insolvency whereby the magnitude of the loss exceeds the injurer's assets.[228] In the latter case the injurer will indeed only consider the risk as one where he could at most lose his own assets and will set his standard of care accordingly. When he, under a duty to insure, is exposed to full liability, the insurer will obviously have incentives to control the behavior of the insured. Via the traditional instruments for the control of moral hazard, the insurer can make sure that the injurer will take the necessary care to avoid an accident with the real magnitude of the loss. Thus, Jost and Skogh argue that compulsory insurance can, provided that the moral hazard problem can be cured adequately, provide better results than they could under the judgment-proof problem.

Indeed, this economic argument shows that insolvency may cause potentially responsible parties to externalize harm: they may be engaged in activities that may cause harm that can largely exceed their assets. Without financial provisions these costs would be thrown on society and would hence be externalized instead of internalized. Such an internalization can be reached if the insurer is able to control the behavior of the insured. This shows that if the moral hazard problem can be cured adequately, insurance leads to even higher deterrence than a situation without liability insurance and insolvency.

Notwithstanding this advantage of liability insurance, the literature has pointed equally to many dangers of compulsory insurance, and has thus formulated several warnings.[229] They can be summarized as follows:

Compulsory insurance should only be introduced when there is a sufficient supply of differentiated insurance policies on the market. This supposes that sufficient competition within insurance markets exists, and that operators have the possibility to actually seek coverage.

Therefore, compulsory insurance should only be introduced when sufficient information is available to insurers on the particular risk that will be covered. If too little information is available on the risk, the risk may be uninsurable, or the risk premium (to account for insurers ambiguity) may be so high that the insured

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227. Peter J. Jost, *Limited Liability and the Requirement to Purchase Insurance*, 16 INT'L REV. L. & ECON. 259, 259-70 (1996). A similar argument has been formulated by Mattias K. Polborn, *Mandatory Insurance and the Judgment-Proof Problem*, 18 INT'L REV. L. & ECON. 45, 45-58 (1998) and by Göran Skogh, *Mandatory Insurance: Transaction Costs Analysis of Insurance*, *in* ENCYCLOPEDIA OF LAW AND ECONOMICS 521-537 (Bouckaert & De Geest eds., 2000). Skogh has also pointed out that compulsory insurance may save on transaction cost.

228. Howard Kunreuther & Paul Freeman, *Insurability, Environmental Risks and the Law*, *in* THE LAW AND ECONOMICS OF THE ENVIRONMENT 316 (Heyes ed., 2001).

229. *See* Faure, *supra* note 225.

are unwilling to pay such a high premium.

Information on the risk for insurers is also crucial since insurers need to be able to control the moral hazard problem through an appropriate risk differentiation.

Compulsory insurance should never be accompanied with a duty to accept particular risks or operators that would be imposed on insurers. An insurance company should, in principle, always keep the possibility to refuse coverage to particularly high-risk individuals. Such a refusal by an insurer can be an instrument of risk differentiation, necessary to remedy moral hazard.

VIII. CONCLUDING REMARKS

Our paper aimed at analyzing the liability for potential damage resulting from GMOs. As we showed in Section II, notwithstanding the beneficial effects, the use of GMOs can potentially also lead to substantial damage, although many of the consequences are still uncertain. The first cases concerning damage caused by GMOs have also already been tried before (mainly United States) courts. Most of these cases concerned claims by organic farmers that their products were negatively affected by the presence of GMOs (so-called commingling or admixture).

Although there are already several contributions dealing with liability for damage caused by GMOs, the central goal of our paper was to address this issue from the perspective of the economic analysis of law. We showed that it is important to distinguish on the one hand the situation where damage results from admixture (between GMO and non-GMO crops) and where damage has been caused to third parties.

The main difference between the two situations is that in the first case, there may be a contractual relationship between injurer and victim, which may, from an economic perspective, call for the application of the so-called Coase Theorem. However, when damage is suffered by third parties, transaction costs are prohibitive, and hence the legal system will have to intervene to determine how to internalize the externalities resulting from the GMO liabilities.

There is, however, one case where the Coase Theorem and contractual liability may still play a role, which is product liability. As we indicated, the economic analysis of product liability relies heavily on assumptions concerning the ability of a victim to obtain accurate information about the product risk. The victim would, taking into account the potential damage and hidden defects, only base his decision on the full price of a product. However, given the fact that many victims may be uninformed of potential product defects, this analysis may not be very useful. It was particularly for that reason that economic theory showed that in the case of underestimation of the risks by consumers, strict liability may be an appropriate liability rule. Only strict liability provides incentives to manufacturers to adopt both an optimal care level as well as an optimal activity (production) level.

Most cases in practice concerned the situation where the victims were not consumers of the GMO, but were rather third parties and more particularly neighbors (organic farmers) from farmers using GMOs.

This is typically also the case when damage is caused to the environment and where the "victim" may be the government, who sues on behalf of the environment. Given the fact that in those cases it is unlikely that the victim itself may have a great influence on the accident risk, economic analysis predicts that these are cases where also a strict liability rule may be warranted. We indicated that this may be different only in the situation where the victim may not be an individual but rather a corporate entity. In those cases, corporations can sometimes also take measures to reduce risks, which would make the situation bilateral. In that case, liability rules should also provide incentives to the potential victim to adopt optimal care and activity levels. The strict liability rule is thus most likely indicated when individuals are victims, whereas negligence may be indicated in bilateral situations where both injurer and victim are corporate entities who could take adequate measures to reduce the risk.

We also indicated that to a large extent, regulation will have an important influence on the scope of liability. However, economic analysis indicates that whereas a breach of regulation may give rise to a finding of liability, the reverse is not necessarily true: following a regulatory standard (e.g., concerning the way in which one should deal with the GMOs) does not necessarily reduce or exclude liability. Indeed, it is quite possible that the efficient care standard is higher than the level required under regulation. For that reason, it is important to still hold the potential injurer liable even if he followed the regulatory standard. Thus, supplementary incentives could be provided through the complementary use of liability rules.

An important problem in any environmental liability case and also in the case of damage suffered as a result of exposure to GMOs is the issue of causation. The few cases that have already dealt with GMO liability show that causation is an important issue to be dealt with in case law. We indicated that economic analysis proposed the use of a proportionate liability rule to deal with uncertainty over causation. The advantage of this approach is that the inefficiency and unfairness of so-called "all-or-nothing" approaches are avoided, and the injurer is exposed precisely to the extent that he contributed to the risk. Moreover, a proportionate liability rule has the advantage of allowing the judge to simply follow the indications provided by experts on the likelihood that a specific damage was caused by an exposure to GMOs.

We pay specific attention to the influence of uncertainty of liability for damage caused by GMOs by asking the question of whether the precautionary principle could have an influence in the liability setting.

In addition, with respect to the unforeseeability defense, we observe that the foreseeability requirement could take into account some possible damage by GMOs that have been discussed. Since the prevailing uncertainties on these

impacts may serve as evidence for the unforeseeability of the impacts, applying the precautionary principle might induce the courts to lower their foreseeability requirement. In this case, the currently available findings on these impacts function as early warnings to indicate that these impacts are foreseeable by the present state of knowledge. However, if the application of the precautionary principle is interpreted as holding the GM operator liable for any damage simply because the damage is itself the evidence indicating the failure to take the precautionary measure, the cost incurred by the GM operator will be high because the operator will be induced to continue taking higher levels of care. The operator will stop doing it only if the benefits of not taking higher level of care are much higher than the cost of taking the higher level of care.

We also addressed the question of channeling liability. Generally, economists have a negative impression of exclusive channeling, suggesting that it is inefficient with a specific operator (or problematic from an economic perspective). This is understandable to the extent that it means others besides the channel party could no longer be held liable and thus would have no incentives for risk reduction. On the other hand, some of the court cases have shown that it was not always easy to construe a case against the manufacturer of GMOs, which would effectively lead to forcing potential victims (often neighboring farmers) to sue all other farmers from which the source of the admixture could come rather than the producer of the GMO who was at the source of the problem. This could be solved by a channeling wherein the GMO producer would be the primary liable party. This makes sense to the extent that the producer can monitor the use of GMOs by its customers (the farmers) via specific agreements that also provide, for example, how particular crops have to be planted. However, a channeling of liability to the manufacturer should not necessarily mean that it is an exclusive channeling, excluding liability of all other parties involved.

As far as defenses are concerned, we indicated that undoubtedly contributory negligence may play an important role, especially in those cases where victims can have an influence on the accident risk. If a strict liability rule were introduced, it is important to add a contributory negligence defense.

Of course the liability for damage caused by GMOs is a very complex issue, and we were therefore not able to discuss all potential aspects. One important aspect not addressed in our paper is how to deal with damage of a transboundary nature resulting from GMOs. There is surely a reason to address this issue since the Cartagena Protocol on Biosafety has urged the Parties of the Protocol to adopt rules and procedures on liability and redress for transboundary damage resulting from the release and movement of GMOs. In this regard, the Ad Hoc Working Group of Legal and Technical Experts on Liability and Redress in the Context of the Cartagena Protocol has discussed some proposals on various issues regarding liability and redress, including the standard of liability, compensation mechanisms, and the definition of transboundary damage. In our view, economic analysis on those proposals are of paramount importance to the discussions in

Working Group because the analysis could provide the Working Group with information concerning the rules and procedures that could offer the optimal protection for the potential victims and give incentives for the potential injurers to take the optimal preventive measures.

Another issue is how adequate compensation for damage caused by GMOs could be provided. We stressed the role of liability rules and liability insurance in that respect, but other instruments (first party insurance, compensation funds) could also serve a role. These, and undoubtedly other aspects, certainly merit further research.

IX. APPENDIX

In the text, it was explained that the benefits of not investing in safety and the costs of not conducting safety measures depend on the degree of growth rate and the level of uncertainty. At time t, those benefits and costs are:

$$dB = \alpha B dt + \sigma B dz_B \tag{1}$$

$$dC = \lambda C dz_C \tag{2}$$

Stochasticities in the above equations are represented by dz_B and dz_C, of which correlation is defined by the following expectation equation:

$$E[dz_C dz_B] = \xi dt \tag{3}$$

As explained in the text, the objective of the decision maker is to maximize the payoff between B and C. Hence, the objective can be written as:

$$F(B,C) = E[e^{-\rho t}(B - C)] \tag{4}$$

Let $x = \frac{B}{C}$, and let also $F(B, C) = Ch(x) = Ch\left(x = \frac{B}{C}\right)$
Hence, equation (4) can be rewritten as:

$$Ch(x) = Ch\left(x = \frac{B}{C}\right) = F(B, C) = E[e^{-\rho t}(B - C)] \tag{5}$$

$$= CE\left[e^{-\rho t}\left(\frac{B}{C} - 1\right)\right] \tag{5.1}$$

$$= CE[e^{-\rho t}(x - 1)] \tag{5.2}$$

The derivative of F(B,C) with respect to t is

$$\frac{\partial F}{\partial t} = -\rho e^{-\rho t}(x - 1) = \rho Ch(x) \tag{5.3}$$

Equation (5.1) can also be written as:

$$h\left(x = \frac{B}{C}\right) = \frac{F(B, C)}{C} = \frac{CE[e^{-\rho t}(x - 1)]}{C} = E[e^{-\rho t}(x - 1)] \tag{6}$$

Consider that $F(B, C) = Ch(x) = Ch\left(x = \frac{B}{C}\right)$, which means:

$$\frac{\partial F}{\partial B} = \frac{\partial F}{\partial x} \cdot \frac{\partial x}{\partial B} = h'(x) \tag{7.1}$$

$$F(B,C) = Ch(x) \Rightarrow$$

$$\frac{\partial F}{\partial C} = \frac{\partial Ch(x)}{\partial C} = h(x) + C\left[h'(x) \cdot \frac{\partial x}{\partial C}\right] = h(x) - xh'(x) \tag{7.2}$$

Using Itô's lemma to dF (B,C), we find:

$$dF(B,C) = \frac{\partial F}{\partial t}dt + \frac{\partial F}{\partial B}dB + \frac{\partial F}{\partial C}dC + \frac{1}{2}\frac{\partial}{\partial B}\left(\frac{\partial F}{\partial B}\right)\left(\frac{\partial B}{\partial Z_B}\right)\left(\frac{\partial B}{\partial Z_B}\right)dt + \frac{1}{2}\frac{\partial}{\partial C}\left(\frac{\partial F}{\partial C}\right)$$

$$\left(\frac{\partial C}{\partial Z_C}\right)\left(\frac{\partial C}{\partial Z_C}\right)dt + \frac{1}{2}\frac{\partial}{\partial B}\left(\frac{\partial F}{\partial C}\right)\frac{\partial B}{\partial Z_B} \cdot \frac{\partial C}{\partial Z_C}\xi dt + \frac{1}{2}\frac{\partial}{\partial B}\left(\frac{\partial F}{\partial C}\right)\frac{\partial B}{\partial Z_B} \cdot \frac{\partial C}{\partial Z_C}\xi dt$$

$$= \frac{\partial F}{\partial t}dt + \frac{\partial F}{\partial B}dB + \frac{\partial F}{\partial C}dC + \frac{1}{2}\frac{\partial^2 F}{\partial B^2}\left(\frac{\partial B}{\partial Z_B}\right)^2 dt + \frac{1}{2}\frac{\partial^2 F}{\partial C^2}\left(\frac{\partial C}{\partial Z_C}\right)^2 dt + \frac{\partial^2 F}{\partial B \partial C} \cdot \frac{\partial B}{\partial Z_B} \cdot \frac{\partial C}{\partial Z_C}\xi dt \tag{8}$$

Consider now equations (1) and (2):

$$dB = \alpha B dt + \sigma B dz_B$$

The derivative of B with respect to dz_B is:

$$\frac{\partial B}{\partial z_B} = \sigma B \tag{9.1}$$

And,

$$dC = \lambda C dz_C$$

The derivative of C with respect to dz_C is:

$$\frac{\partial C}{\partial z_C} = \lambda C \tag{9.2}$$

Equation (8) can be rewritten as:

$$dF(B,C) = -\rho Ch(x)dt + h'(x)dB + [h(x) - xh'(x)]dC + \frac{1}{2}h''(x).\frac{1}{C}(\sigma B)^2dt +$$

$$\frac{1}{2}\frac{x^2}{C}h''(x).(\lambda C)^2dt + \left[-xh''(x).\frac{1}{C}\right](\sigma B)(\lambda P)\xi dt = -\rho Ch(x)dt + h'(x)dB + [h(x)$$

$$- xh'(x)]dB + \frac{1}{2}h''(x)x^2C\sigma^2dt + \frac{1}{2}x^2\lambda^2Ch''(x)dt - x^2C\lambda\sigma h''(x)\xi dt \quad (10.1)$$

Since $dB = \alpha Bdt + \sigma Bdz_B$, and $dC = \lambda Cdz_C$, equation (10.1) can be rewritten as:

$$dF(B,C) = -\rho Ch(x)dt + h'(x)\alpha Bdt + h'(x)\sigma Bdz_B + [h(x)$$

$$- xh'(x)]\lambda Cdz_C + \frac{1}{2}h''(x).x^2C\sigma^2dt + \frac{1}{2}x^2\gamma^2Ch''(x)dt - x^2C\sigma\lambda h''(x)\xi dt$$

(10.2)

As stated earlier, the objective of the decision maker is to maximize the payoff between B and C. This objective is expressed in terms of the expected value between B and C in equation (4). This is an important assumption because, by definition, the expected value of Brownian motion is zero. As a result, all expressions in equation (10.2) that contain the properties of Brownian motion, namely dz_C and dz_B, should equal to zero. Hence, equation (10.2) can be rewritten as:

$$dF(B,C) = -\rho Ch(x)dt + h'(x)\alpha Bdt + \frac{1}{2}h''(x)x^2C\sigma^2dt +$$

$$+ \frac{1}{2}x^2\lambda^2Ch''(x)dt - x^2C\sigma\lambda h''(x)\xi dt \quad (10.3)$$

$$= -\rho h(x) + \alpha xh'(x) + \frac{1}{2}\{x^2\sigma^2h''(x) - 2\xi\lambda\sigma x^2h''(x) + x^2\lambda^2h''(x)\}$$

(10.4)

Defining $dF = 0$, we find:

$$-\rho h(x) + \alpha xh'(x) + \frac{1}{2}\{x^2\sigma^2h''(x) - 2\xi\lambda\sigma x^2h''(x) + x^2\lambda^2h''(x)\} = 0$$

(11)

The boundary conditions for equation (11) are:

$$h(x^*) = h^* - 1$$

$$h'(x^*) = 1$$

A natural solution of equation (11) is $h(x) = Ax^{\beta}$, where:

$$h'(x) = \beta A x^{(\beta - 1)} = \beta A \frac{x^{\beta}}{x}$$

$$h''(x) = \beta(\beta - 1) A x^{(\beta - 2)} = \beta(\beta - 1) A \frac{x^{\beta}}{x^2}$$

Substituting this solution and its derivatives into equation (11), we find:

$$-\rho A x^{\beta} + \alpha x \beta A \frac{x^{\beta}}{x} + \frac{1}{2}\left\{x^2\sigma^2\beta(\beta - 1)A\frac{x^{\beta}}{x^2} - 2\xi x^2\sigma\lambda\beta(\beta - 1)A\frac{x^{\beta}}{x^2} + x^2\lambda^2\beta(\beta - 1)A\frac{x^{\beta}}{x^2}\right\} = 0 \Leftrightarrow \frac{1}{2}(\sigma^2 - 2\xi\sigma\lambda + \lambda^2)\beta^2 + \left\{\alpha - \frac{1}{2}(\sigma^2 - 2\xi\sigma\lambda + \lambda^2)\right\}\beta - \rho = 0 \quad (12)$$

From equation 12, we find the value of β as follows:

$$\beta = -\frac{\left(\alpha - \frac{\sigma^2 - 2\xi\sigma\lambda + \lambda^2}{2}\right)}{(\sigma^2 - 2\xi\sigma\lambda + \lambda^2)} \pm \sqrt{\frac{\left(\alpha - \frac{\sigma^2 - 2\xi\sigma\lambda + \lambda^2}{2}\right) - (\sigma^2 - 2\xi\sigma\lambda + \lambda^2)\rho}{(\sigma^2 - 2\xi\sigma\lambda + \lambda^2)}} \quad (13)$$

Let us now reconsider the boundary conditions for equation (11), namely:

$$h(x^*) = h^* - 1 \quad (14a)$$

$$h'(x^*) = 1 \quad (14b)$$

A natural solution of equation (11) is $h'(x) = A(x^*)^{\beta}$, where:

$$h'(x^*) = \beta A(x^*)^{(\beta-1)} = \beta A \frac{x^{*\beta}}{x^*} \tag{14c}$$

Substituting (14c) into (14b):

$$\beta A \frac{x^{*\beta}}{x^*} = 1 \Rightarrow A x^{*\beta} = \frac{x^*}{\beta} \tag{14d}$$

Substituting (14d) into (14a):

$$\frac{x^*}{\beta} = x^* - 1 \Rightarrow x^* = \frac{\beta}{\beta - 1} \tag{14e}$$

Since $x = \frac{B}{C}$, equation (14e) means that:

$$\frac{B}{C} = \frac{\beta}{\beta - 1} \tag{15}$$

In equation (15), the right hand expression, $x^* = \frac{\beta}{\beta - 1}$, functions as the precautionary multiplier Γ for cost-benefit ratio.